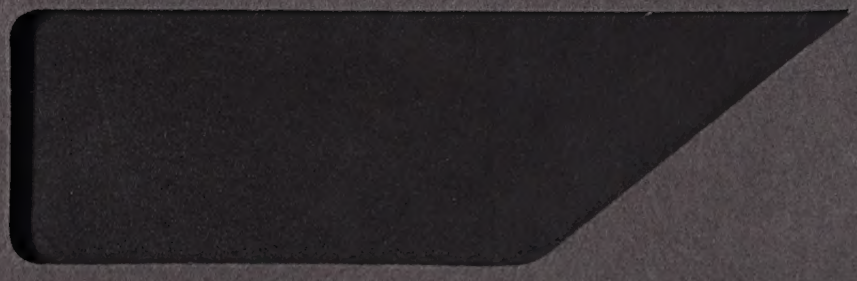
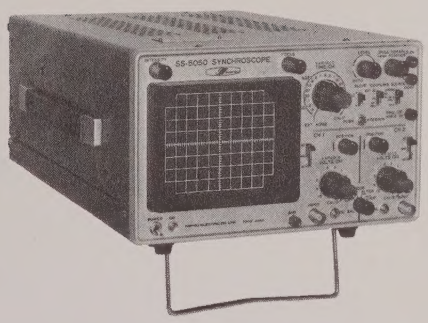
667

INSTRUCTION MANUAL

SYNCHROSCOPE SS-5050

IWATSU ELECTRIC CO., LTD.
TOKYO, JAPAN





SYNCHROSCOPE
SS-5050

1481901 ~ APRIL 1971

INSTRUCTION MANUAL

FOR

SYNCHROSCOPE SS-5050

IWATSU ELECTRIC CO., LTD.

TOKYO, JAPAN

Thank you for your purchasing
IWATSU Synchroscope SS-5050.

The IWATSU SS-5050 SYNCHROSCOPE is a compact, lightweight and portable type synchroscope of simplified operation. The ample experience and inexaustible originality of IWATSU's engineers in this field made the development and production of this extraordinary high performance SYNCHROSCOPE possible.

As a result of their unique design, the quality of IWATSU's electronic instruments are highly warranted. Transformers and rotary switches are designed for electronic instrument use, and then manufactured in our factory under strict quality control. These components are warranted for the life of the instrument.

Semiconductors and other precise components are selected from a wide range of top-ranking foreign and domestic products, and only those which pass our severe tests are employed in our instrument.

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GENERAL

The SS-5050 SYNCHROSCOPE is a compact, lightweight, and portable type synchroscope of simplified operation.

The electronically switched dual-trace vertical deflection system features the wide bandwidth (DC to 5 MHz) even in the highest sensitivity range (10 mV/cm for both channels). Extremely high stability is obtained by the use of FET (Field Effect Transistor) in the input circuit. Measurements can be performed only 15 seconds after switching the power on.

The horizontal deflection system provides the trigger signal in which DC (external trigger) to 5 MHz signals can completely be triggered.

The 5 inch circular CRT with an internally marked graticule provides an 80 mm (Y axis) x 100 mm (X axis) parallax-free display.

COMPOSITION

The instrument is composed of the following articles.

ACCESSORIES:

Nomenclature	Quantity
Connection lead (black)	1
Connection lead (red)	1
Probe (1016B1, 1016B2)	2
Post adapter	2
Hexagonal wrench (4 mm)	1
Hexagonal wrench (3 mm)	1
Screw driver	1
Dust cover	1
Accessory kit	1
Instruction manual	1
Inspection report	1

In this chapter, the performance of the instrument necessary to assure accurate measurements is briefly described. Refer to "Description of Panel Controls" in Chapter 2, for information on the knobs and connectors mentioned in this chapter.

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VERTICAL DEFLECTION SYSTEM

The preamplifier of the vertical deflection system comprises an electronically switched dual-trace system. The cahracteristics and accuracy in the following description are applicable to both CH 1 and CH 2 unless otherwise specified.

Deflection Sensitivity

Ten (10) calibrated ranges from 10 mV/cm to 10 V/cm are provided to ensure an optimum deflection sensitivity for any measurement. In other words, the maximum deflection sensitivity which has been calibrated at the factory is 10 mV/cm. Variable attenuation is possible with the VARIABLE control which decreases the sensitivity 1/2.5 (or more) of the calibrated value in each range. Thus a low sensitivity of approximately 25 V/cm is available.

The accuracy of the highest sensitivity, 10 mV/cm, can be calibrated to 0 % tolerance with the internal GAIN controls. (R114 for CH 1 and R134 for CH 2). The accuracy of any range above 20 mV/cm can be calibrated to a tolerance of $\pm$3 %.

Bandwidth

The bandwidth corresponding to the position of the AC-GND-DC switch is:

DC	DC to 5 MHz (within -3 dB)
AC	Approx. 3 Hz to 5 MHz (within -3 dB)

The frequency response difference between CH 1 and CH 2 is within 1 dB at 5 MHz.

Rise Time

70 nsec (nsec = nanosecond = 10^{-9} second)

Square Wave Characteristics

The values shown below are for an input square wave with a rise time of less than 20 nsec.

Overshoot	3 % or less
Ringing	2 % or less
Sag (at 60 Hz)	5 % or less

Input Signal Coupling Mode

Three (3) coupling modes, AC, DC and GND (to identify the ground potential display) are available. In the AC position, the input signal is coupled through a blocking capacitor, and in the DC position DC coupling is effected.

Input Impedance

Direct	1 megohm	shunted by 40 pF or less
With probe (10:1)	10 megohms	shunted by approx. 14 pF

Maximum Allowable Input Voltage

The maximum allowable input voltage differs with the type of signal to be measured (hereafter referred to as input signal) as shown in Table 1-1. (Refer to Fig. 1-1.)

Table 1-1

Input signal connection mode	Maximum allowable input voltage
Direct connection to the input terminal	500 V (DC + AC peak)
When input is connected to the probe	600 V (DC + AC peak)

Mode Selection

CH 1	CH 1 only
CH 2	CH 2 only
ALTER	Alternate sweep of CH 1 and CH 2
CHOP	Chopped switching (at 100kHz or more) of CH 1 and CH 2

Linearity

When a signal displayed at the center of the CRT with a vertical amplitude of 20 mm is moved to the top or bottom of the horizontal graticule scale within 80 mm, the variation in the vertical amplitude of the display is within ± 2.5 % (± 0.5 mm).

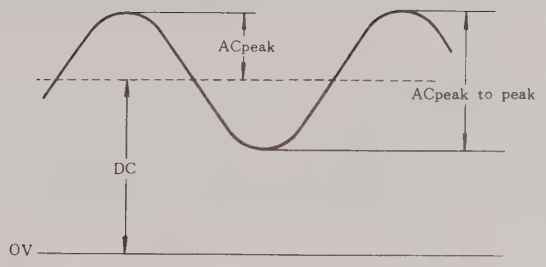


Fig. 1-1

Drift

The drift, or vertical shift of a display is less than 10 mm/hour, when measured 5 minutes or more after the power is applied.

Internal Trigger Selection

In the internal triggering mode, the display can be triggered by either the common output from the vertical deflection system or by the input signal of CH 2 (CH 2 ONLY).

HORIZONTAL DEFLECTION SYSTEM

Sweep Selection

EXT HORIZ (external sweep) can be provided in addition to the normal sweep.

Sweep Time (TIME/CM)

Nineteen (19) calibrated sweep times from 0.5 μsec/cm to 0.5 sec/cm are available. Continuous variation of the sweep time is also possible by using the VARIABLE knob which reduces the rated sweep time by 2.5 times (or more). The lowest sweep time is 1.25 sec/cm (or more).

The accuracy of each range with VARIABLE knob turned extremely clockwise is within ±5 % of the rated value.

Sweep Magnifier

The display can be horizontally magnified by 5 times. Accuracy of sweep time is within ±10 % of the unmagnified sweep time.

Maximum Sweep Time

The maximum sweep time of the TIME/CM switch, which is normally 0.5 μsec/cm, can be accelerated by 0.1 μsec/cm by use of the sweep magnifier.

Sweep Linearity

The sweep linearity at any position of the TIME/CM switch is within ±10 % of the rated value, excluding, however, the magnification with the TIME/CM at 0.5 μsec/cm.

External Sweep

See Table 1-2 below.

Table 1-2

Item	Performance and Accuracy
Input Impedance	1 Megohm within 30 pF
Deflection Sensitivity	Within 0.2 V/cm ±5 %, can be attenuated 1/8 or more with VARIABLE
Frequency Response	Within -3 dB, in the range DC to 300 kHz
Applicable Bandwidth Phase (Frequency Ratio) Measurement	DC to 10 kHz (phase difference 3 degrees or less at 10 kHz)

Triggering

Type of Trigger Signal Source (TRIG SOURCE)

The trigger signal source can be divided into the internal (INT) and external (EXT). The INT trigger signal can be selected from NORM or CH2 ONLY.

Polarity (SLOPE)

+ Trigger (triggered by the positive going slope of input signal)

- Trigger (triggered by the nagative going slope of input signal)

Trigger Input Coupling Mode (COUPLING)

Three types of trigger coupling modes are available: EXT DC, AC, and HF REJ. The triggering frequency range of each mode is shown in Table 1-3.

Input Impedance of the External Trigger Signal Input Terminal (TRIG OR HORIZ IN)

1 megohm shunted by 30 pF or less

Auto and Normal Trigger Mode

By turning LEVEL switch fully counterclockwise, Normal trigger can be switched to Auto trigger. In the Auto mode, the sweep circuit will not be triggered by signals below 50 Hz. When a trigger signal is not present, the sweep will free run. In the Normal trigger mode, signals above 10 Hz will be used to trigger (from DC, for external trigger). When trigger is not present, only a spot will appear on the CRT.

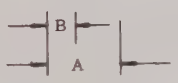
Table 1-3 Triggerable Frequency Range and Level
(In the AUTO triggering mode, the sweep is not triggered by signals lower than 50 Hz, even if the COUPLING switch is in the EXT DC position.)

Coupling	Triggerable Frequency Range	Trigger Level	
		Internal Trigger (Display Amplitude)	External Trigger (Voltage)
EXT DC	DC ~ 2 MHz	-	0.5 Vp-p or more
	2 MHz ~ 5 MHz	-	2 Vp-p or more
AC	10 Hz ~ 50 Hz	10 mm or more	1 Vp-p or more
	50 Hz ~ 2 MHz	5 mm or more	0.5 Vp-p or more
	2 MHz ~ 5 MHz	20 mm or more	2 Vp-p or more
HF REJ	10 Hz ~ 50 Hz	10 mm or more	1 Vp-p or more
	50 Hz ~ 10 kHz	5 mm or more	0.5 Vp-p or more

CALIBRATOR

The calibration voltage is obtained from the CAL OUT connector. Characteristics of this output are shown in Table 1-4.

Table 1-4

Item	Characteristics and Accuracy
Voltage	Two ranges: -0.04 V and -0.4 V, within ±3 %
Frequency	Line frequency (50 Hz or 60 Hz)
Waveform	Square wave
Duty Ratio	 $\frac{B}{A}$ X 100 = 35 ~ 45
Output Impedance	5 ohms for 0.04 V range 50 ohms for 0.4 V range

CATHODE RAY TUBE CIRCUIT

Cathode Ray Tube

Type	5DEP1 or 130ARB1, 5-inch circular type
Effective Display Area	80 mm (vertical) x 100 mm (horizontal)
Acceleration Voltage	1,450 V between cathode and ground

External Intensity Modulation

Minimum intensity modulation voltage	5 Vp-p ~ 100 Vp-p
Input impedance	47 kilohms, within 30 pF
Maximum allowable input voltage	200 Vp-p

POWER REQUIREMENTS

Voltage Range

This instrument can be operated with the line voltage (commercial power source) shown in Table 1-5, by selecting an appropriate position of voltage selector switch located on the rear panel. (This model can be changed to 200 V power use upon request.)

Table 1-5

Source Voltage	Line Voltage Range Switch Position	Applicable Line Voltage Range
100 V	100 V	90 ~ 110 V
	115 V	105 ~ 126 V
200 V	200 V	180 ~ 220 V
	230 V	207 ~ 253 V

Line Frequency

50 Hz/60 Hz

Power Consumption

Approx. 32 W

ENVIRONMENTAL CONDITIONS

Temperature Range

The environmental temperature range for normal operation of this instrument is from -10°C to 40°C.

Humidity Range (Relative Humidity)

This instrument operates normally with a relative humidity of up to 85 % at 40°C.

Vibration

This instrument will operate normally after a vibration test wherein the instrument is subjected to vibrations with an amplitude of 1.5 mm at 1000 cycles per minute along each of the three major axes for one hour.

Shock

Operation of this instrument should be normal after three shock tests for each major axis. This can be performed by raising one edge of the equipment 5 cm above a rigid test bed (or, an incline of 30 degrees, whichever is smaller) and releasing it.

CONSTRUCTION

Dimensions

Approx. 270 mm W x 156 mm H x 380 mm L

Weight

Approx. 7 kg

Color

Front Panel	White aluminum finishment
Cabinet	MUNSELL 5GY5/0.5 Leather tone

For effective use of this instrument, the operator must be familiar with the functions and operation.

In this chapter, the functions of panel controls and practical operating procedures will be described.

When this instrument is to be used immediately, the first part of this chapter may be bypassed and the section "Operating Procedure" on page 2-10 shall be referred to.

Carrying and Use 2-1
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- Applying Power and Obtaining a Sweep 2-11
- Operation from Signal Coupling to Triggering Signal Coupling 2-12
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Carrying and Use

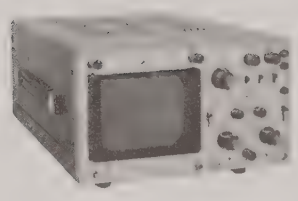
As seen from Fig. 2-1, there are two different way of carrying this instrument. When the instrument is to be carried over a long distance, the method shown in Fig. 2-1 (a) should be followed. The method shown in Fig. 2-1 (b) is suitable for carrying it for a short distance.

Exercise care in protecting the instrument from excessive shocks and vibrations when carrying. Special care should be taken for the front panel when carrying the instrument in the shoulder bag. Shoulder bags are available upon request.

(a) (b)

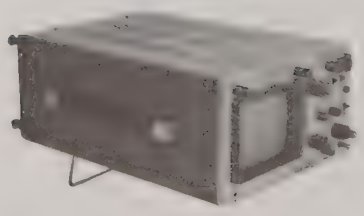
Fig. 2-1

This instrument can be operated in the four different positions shown in Fig. 2-2, depending upon the situation. When it is used in the vertical position, be extremely careful so as not to tip it over by excessive pulling on the probe. When the operating position is changed, the vertical position of the trace on the CRT may shift slightly. This is not abnormal. The trace will return to its original position in approximately 1 minute.

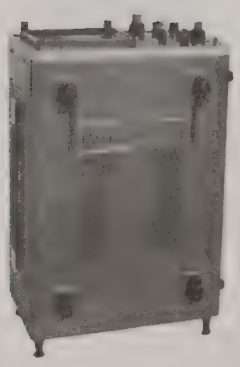


(a)

(b)



(c)



(d)

The supporter of drawing (b) shall be interchanged to one of drawing (c).

Fig. 2-2

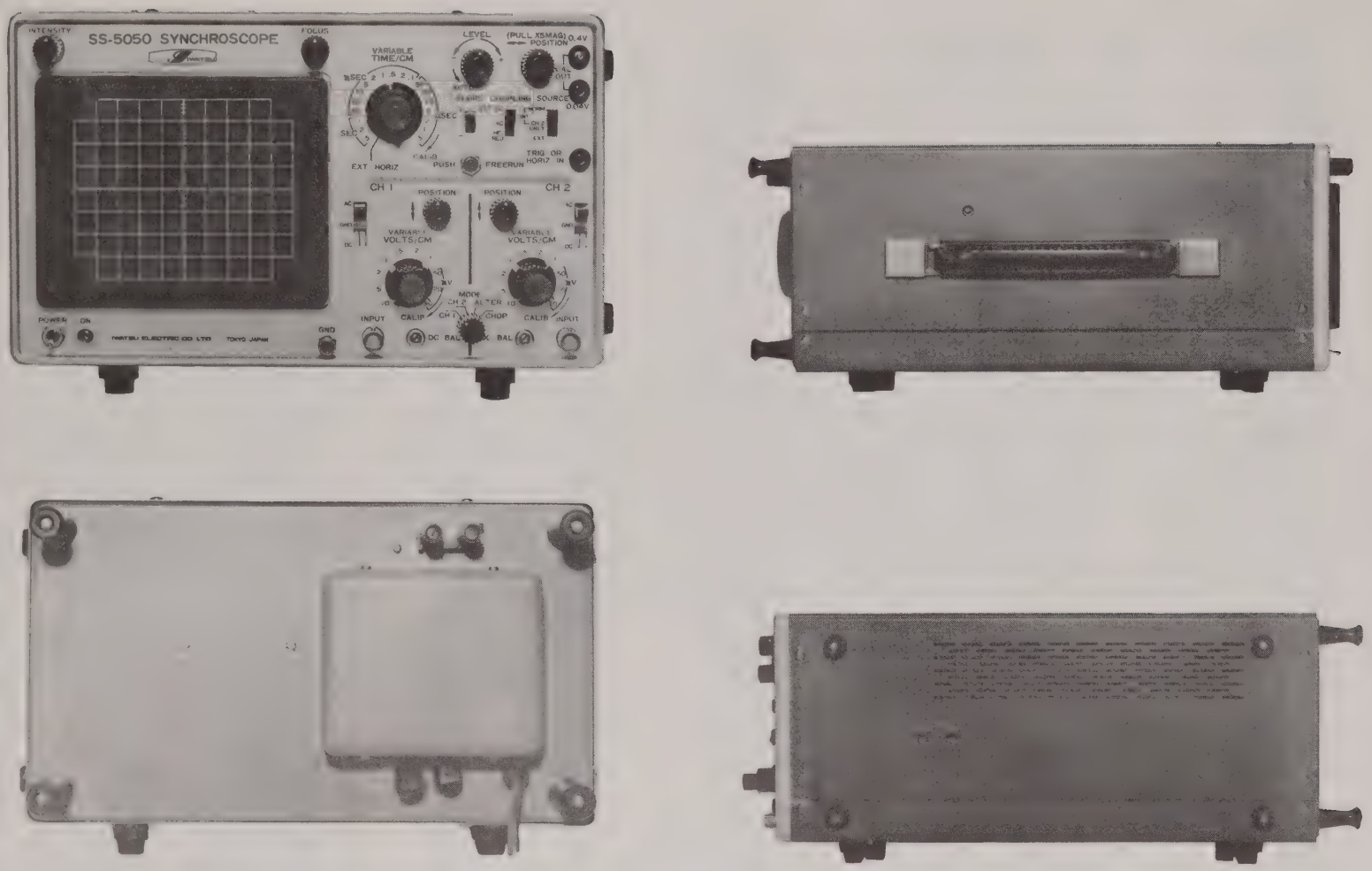

SS-5050 SYNCHROSCOPE
INTENSITY
FOCUS
VARIABLE TIME/CM
LEVEL
(PULL XSMAG) POSITION
0.4V
SOURCE
EXT HORIZ
CAL-Φ PUSH
FREERUN
TRIG OR HORIZ IN
CH 1
CH 2
POSITION
VARIABLE VOLTS/CM
MODE
CH 1
CH 2 ALTER
CHOP
INPUT
CALIB
DC BAL
POWER
ON
GND
TOKYO JAPAN

Fig. 2-3

DESCRIPTION OF PANEL CONTROLS

The function and/or purpose of switches, controls, and connectors on the front and rear panels will be described. For concentric knobs, the black markings on the panel indicate the black knob position, and the red markings indicate the position of the red knob. Refer to Fig. 2-3.

Front Panel

——Power Supply and CRT Circuit——

INTENSITY

Controls brightness of trace or spot. The trace is intensified by clockwise rotation of this control, and de-intensified by counterclockwise rotation. A spot will appear only when the TIME/CM (& EXT HORIZ) switch of this instrument is set to the EXT HORIZ position.

FOCUS

A control to focus the trace or spot on the CRT. This control is operated in conjunction with the ASTIG located on the left side panel.

POWER

A line switch. Turned to ON at the upper side and OFF at the lower side. Power ON is indicated by the pilot lamp.

ON

A pilot lamp. When the power is supplied, this lamp is lit, and the power is off, it goes off.

——Vertical Deflection System——

Corresponding controls and connectors for CH1 and CH2 function identically, therefore these will be described collectively, for CH1 only.

MODE

Determines operating mode of dual trace vertical axis amplifier. The following modes are available.

CH 1

Selects CH1 amplifier only. In this position, the instrument operates as a single trace synchroscope.

CH 2

Selects CH 2 amplifier only. The instrument also operates as the single trace synchroscope.

ALTER

Operation of CH 1 and CH 2 is alternately switched after each horizontal sweep.

Signals connected to these inputs are displayed alternately. Simultaneous display of each signal becomes impossible at slow sweep speeds (below approx. 2 msec/cm). The ALTER mode is suitable for comparatively high frequency input signals.

CHOP

Signals from CH 1 and CH 2 amplifiers are switched at a repetition rate of 100kHz or more, and are simultaneously displayed. In this mode, the signals are displayed as dotted lines, and signals may become inconvenient to observe at high sweep speeds of approximately 50 μsec/cm or above. The CHOP mode operation is preferred for measuring comparatively low frequency signals.

INPUT

A BNC-type connector for connecting input signal or probe.

GND

The earth terminal for connecting the input signal source to earth.

AC-GND-DC

A switch to select the input coupling mode. In the AC position, the input signal is coupled to the vertical axis amplifier through a coupling capacitor. The DC component of the input signal is blocked and only the AC component is displayed. In the DC position, the input signal is directly coupled to allow the display of all components, including the DC component of the input signal.

In the GND position, the input of the vertical axis amplifier is disconnected from the INPUT connector and grounded to aid in determining the ground potential of the display (This is normally used as a reference level for measurement).

VOLTS/CM (Black Knob)

A switch to select a vertical deflection sensitivity from 10 mV/cm to 10 V/cm in 10 steps. An appropriate position must be chosen for adequate display size. When the VARIABLE control is turned fully clockwise (CALIB), the voltage per one division (1 cm) of the graticule is that indicated by the position of the VOLTS/cm switch.

VARIABLE (Red Knob)

A conitnuously variable control to attenuate the input signal. The maximum attenuation ratio of 1/2.5 (or more) is obtained at the fully counterclockwise position of this control. Therefore, continuous attenuation between steps of the VOLTS/CM switch is possible. For quantitative measurement of input signal, the VARIABLE should be set to the CALIB position.

POSITION

A control to adjust the vertical position of the trace or spot. When this control is turned clockwise, the trace moves upward, and it moves down with counterclockwise rotation.

DC BAL

A screwdriver control to balance the DC potential in the vertical axis amplifier. If the potential is not well-balanced, the display will shift vertically as the VARIABLE knob is turned. Once balanced, vertical shift of the display is negligible, unless excessive ambient temperature variations are encountered.

— Horizontal Deflection System —

LEVEL (& AUTO)

Functions both as a potentiometer control with switch. As a potentiometer, selects a trigger point on an input signal waveform at which sweep starts. In the absence of a trigger signal or it does not reach the trigger point, sweep will stop and the instrument will remain in standby status with a spot on the CRT.

When this knob is turned fully counterclockwise, the trigger mode will become auto-trigger mode, in which triggering can be performed for signals 50 Hz or more. If the frequency of the trigger signal is 50 Hz or less, the signal does not reach the trigger point, or in the absence

of the trigger signal, the sweep will become a free-run mode.

TIME/CM (& EXT HORIZ) (Black Knob)

TIME/CM Range

This control is used to select a sweep time from 0.5 μsec/cm to 0.5 sec/cm in 19 ranges. The optimum position for an observation should be determined in accordance with the waveform of the input signal. The sweep time can be directly read from the meter indication by turning the VARIABLE control (described later) fully clockwise.

EXT HORIZ Range

An external sweep mode (XY scope) with the knob turned fully counterclockwise. Operation of the internal sawtooth generating circuit is inactivated, and the horizontal axis is swept by an external signal fed to the TRIG OR HORIZ IN.

VARIABLE (Red Knob)

The VARIABLE control provides two functions; the fine adjustment of sweep time and attenuator of the external sweep signal.

As the attenuator of the sweep signal, the sweep time can be delayed 1/2.5 (or more) times of the indicated value of each range of TIME/CM control. Sweep time is delayed with the counterclockwise rotation of this knob. For quantitative measurement of an input signal, this control should be set to CALIB position.

The input signal applied to the TRIG OR HORIZ IN can be attenuated to approximately 1/8.

POSITION (& PULL X5 MAG)

This knob functions as a variable control and a push-pull switch. As the variable control, it is used for adjusting horizontal position of the spot and trace. This knob should be turned clockwise when the horizontal position is in the left portion of the viewing area, and counterclockwise when the horizontal position is in the right portion. As the push-pull switch, it is used to magnify the display by 5 times (when pulled).

SOURCE

This switch is used to select the trigger signal source or the external sweep. (Refer to "Operation, Proper Triggering" for details.)

INT NORM

Sweep is internally triggered by a portion of the CH 1 and CH 2 input signals fed to the INPUT connector.

INT CH 2 ONLY

Sweep is internally triggered by a portion of the CH 2 input signals fed to the INPUT connector. This mode is used preferably for a dual trace operation (ALTER or CHOP) for positive triggering.

EXT

Sweep is externally triggered. The input signal or a signal of which the timing is a multiple of the input signal must be connected. This connector is also used to connect an external sweep signal. In any case, the input signal should be connected to the TRIG OR HORIZ IN.

COUPLING

Selects trigger signal coupling with the trigger circuit, depending on the type of the trigger signal, in order to insure correct trigger operation. In the external sweep mode, it also selects the input signal coupling. In external sweep operation, however, HF REJ cannot be used. (For further details, refer to "Proper Triggering.")

EXT DC

In this position, the synchroscope provides DC coupling only in an external trigger mode, in which, the synchroscope is triggered by DC. Also in the external sweep mode, this instrument provides DC coupling.

AC

In this position, the trigger mode provides AC coupling. Since the DC component of the trigger signal is rejected, triggering is not affected by the DC component.

HF REJ

A low pass filter is used for coupling. In this mode, high frequency noises or high frequency (approximately 10 kHz or more) trigger signals are rejected.

SLOPE

Selects a positive or negative slope to start the sweep.

TRIG OR HORIZ IN

Connector for an external trigger signal when using the external trigger mode. It is also used to connect an input signal for an external sweep.

Its input impedance is 1 megohm (with a parallel capacitance of 30 pF or less). The maximum allowable input voltage is 500 volts (DC + AC peak). Do not apply excessive input voltages.

CAL OUT

A connector for calibrating voltage output, at which two negative square waves (0.04 V and 0.4 V) appear.

PUSH FREERUN

While this button is being depressed, the sweep circuit is in the freerun mode. Even in the absence of trigger signals, the sweep circuit operates and the instrument is maintained in the freerun mode.

Left Panel

ASTIG

Provides adjustment for optimum trace or spot on the CRT. This volume is controlled in conjunction with FOCUS located on the front panel.

Right Panel

GAIN ADJ CH1, CH2

A control to adjust CH1 and CH2 vertical deflection for uniform sensitivity. In this case the VARIABLE on the front panel should be at the CALIB position.

Rear Panel

Power Cord

Power is supplied when this cord is inserted into the line socket.

100 V ~ 115 V Switch (toggle switch)

A switch to select the applicable power source voltage. In the 110 V position, this instrument operates on a source voltage of 100 V ±10 %, and in the 115 V position, operates on 115 V ±10 %. By a simple change of wiring, this instrument can be operated on 200 V ±10 % or 230 V ±10 % with LINE VOLTAGE RANGE selector switch operation.

1 A

A fuse holder containing a 1 Amp fuse.

Z AXIS IN

A connector for external intensity modulation. The required voltage for intensity modulation is approximately 5 volts.

OPERATING PROCEDURE

The proper operating procedures for this instrument will be described next. The best way to become familiar with the operation of this instrument is to apply various input signals and operate the controls. The internal circuits will not be damaged by mishandling of the panel controls and switches. However, the precautions described in the following item "Pre-start operation" should be observed.

Pre-start Operation

Check Line Voltage

This instrument is designed to operate on the line voltages shown in Table 1-5. Use the correct line voltage. Application of line voltages other than those specified herein will cause trouble.

Ambient Temperature

The ambient temperature range for normal operation of this instrument is from -10°C to +40°C. Avoid using this instrument in conditions exceeding this range.

Do Not Apply Excessive Input Signals

The maximum allowable input voltages which can be applied to the CH 1 or CH 2 INPUT connector, are shown in Table 1-1. Avoid connecting any voltage in excess of these ratings.

Do Not Leave an Intensified Spot for Long Period of Time

Do not operate the instrument with excessive intensity, or with the spot or trace moved off from the CRT screen for extended period of time. This is to prevent burning of the phosphor screen of the CRT and damage to circuit components.

Applying Power and Obtaining a Sweep

Now you are ready to proceed with actual operation.

Turn the Power ON, and Intensity Spot on the CRT

Turn the POWER switch OFF and connect the power cable to the line connector, and place the following controls.

INTENSITY	Fully clockwise
MODE	CH 1
AC-GND-DC (CH 1)	GND
POSITION (CH 1)	Mid range
TIME/CM (& EXT HORIZ)	EXT HORIZ
POSITION (PULL ×5 MAG)	Push, then turn to approximately the mid position

Turn the POWER switch ON. The instrument is operational in approximately 8 seconds after it is turned on. A spot will appear on the CRT. The spot should be excessively bright. Turn the INTENSITY control counterclockwise until the desired intensity is obtained.

Focus the Spot

Adjust the vertical and horizontal POSITIONS alternately to move the spot to the center of the viewing area, then focus the spot with FOCUS and ASTIG controls.

Sweep

Set the TIME/CM (& EXT HORIZ) switch to 1 mSEC range and the LEVEL (& AUTO) to the AUTO position. The sweep should start. Brightness of the trace will increase upon the start of sweep. Adjust the INTENSITY control for proper brightness. As the trace starts from the center of the CRT, turn the horizontal POSITION control counterclockwise to move the sweep starting point to the left edge of the graticule. Turn the TIME/CM and VARIABLE controls and confirm that the sweep time varies in accordance with the controls.

If the sweep speed is more than 50 μSEC, the clearness will be lost and the trace may become invisible. This is not a defect. Then depress the PUSH FREERUN button. While this button is being depressed, the trace will be visible with proper brightness, even if the sweep speed is increased.

Operation from Signal Coupling to Triggering

Signal Coupling

Now, let us try to display the waveform of the calibrating voltage (CAL OUT) on the CRT. Connect the CAL OUT 0.04 V to the CH 1 INPUT connector with the furnished lead. Set the controls as follows:

VOLTS/CM (CH 1)	10 mV
VARIABLE (CH 1)	CALIB position

Change the AC-GND-DC switch to the DC position, and set the TIME/CM switch to the 10 mSEC position. The calibration voltage should be displayed as a square wave approximately 4 cm in amplitude.

Turn the VARIABLE switch counterclockwise and confirm that the amplitude is continuously attenuated. Return the VARIABLE control to the CALIB position, and set the VOLTS/CM switch to the 20 mV position. The display amplitude should become half of the previously displayed one; 2 cm. Then, rotate the VOLTS/CM switch counterclockwise sequentially. The amplitude should be attenuated to each step.

If the amplitude is too attenuated to observe, reconnect the lead to the CAL OUT 0.4 V. The amplitude will be magnified 10 times.

From the above description of operation, how this instrument is operated with input signal with respect to the VOLTS/CM and VARIABLE controls will be known.

Before Triggering

Proper triggering is a key point in operating a synchroscope. In general, the following items must be predetermined prior to triggering the sweep.

(1) Selection of trigger source

Internal trigger (INT) or external trigger (EXT)

(2) Selection of trigger coupling mode

AC, DC, or HF REJ mode

(3) Selection of trigger polarity

Trigger on positive (+) or negative (-) going slope of input signal

(Please refer to the item on "Proper Triggering" for details.)

In this practice, the sweep will be triggered in the AC coupling mode and triggered by the positive going slope of the input signal. Therefore, the trigger controls must be set as follows:

SOURCE	INT NORM
COUPLING	AC
SLOPE	+

Proper Triggering

SOURCE Switch

For stable display of input signal waveforms, the sweep circuit must be triggered by the input signal, or a signal which is a certain (an integer multiple) relation to the input signal with regard to time, - this signal is called the trigger signal.

The triggering method wherein the SOURCE switch is set to the INT position and a portion of the input signal to be measured is internally (from the vertical deflection system) fed to the trigger generator, is called the internal trigger method (INT NORM, INT CH 2 ONLY) (refer to Fig. 2-4). The external trigger method requires the connection of an external signal, having a direct or a certain time relationship to the input signal as the triggering signal for the trigger generator. In this mode, the SOURCE switch must be set to the EXT position also for external sweep.

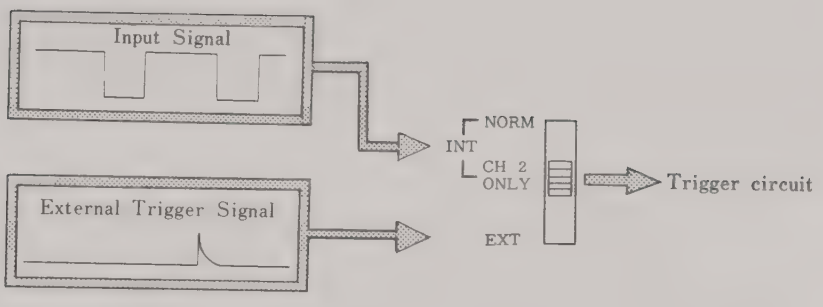


Fig. 2-4 Selection of Trigger Signal with SOURCE Switch

Internal Trigger

In the internal trigger mode, the trigger signal is internally obtained from the vertical deflection system, and even an input signal of very low amplitude is appropriately amplified to an adequate level for triggering. Therefore, panel control operation for this mode is very simple, and the chance that the comparatively low input impedance of the external trigger circuit may load the trigger signal source output is eliminated. From these advantages, it can be seen that internal triggering is generally convenient for measurement.

External Trigger

The shortcomings of external triggering are described under internal trigger operation, however, the external trigger operation still provides the following advantages.

First, the trigger generator is not influenced by the vertical deflection system. For example, the voltage level of the signal, which is fed to the trigger input in the internal trigger mode, varies when the position of the VOLTS/CM switch is changed or the POSITION control is turned. These variations may necessitate readjustment of the LEVEL control every time the position of the VOLTS/CM switch is changed. Conversely, in the external trigger mode, the triggering is stable, once adjusted, regardless of variations in the vertical deflection system, except in the cases where the external trigger signal also varies.

Second, when it is desired to start the sweep a certain period in advance or after a certain time delay to display a particular point on the waveform, and provided that an appropirate triggering signal is available, the external triggering mode facilitates stable observation

of the particular point.

When the SOURCE switch is set to the EXT position, and the amplitude of the external trigger signal is excessively large, proper adjustment of the trigger level with the LEVEL control may be impossible.

Use Proper COUPLING Switch

The COUPLING switch is to select the coupling mode of the trigger signal and the trigger generator. Three coupling modes - EXT DC, AC, and HF REJ - are available. In these modes, the trigger signal and trigger input are connected by a DC coupling for external triggering (or external sweep input when the instrument is used as an X-Y oscilloscope), AC coupling for internal triggering, and HF REJ with the low pass filter as illustrated in Fig. 2-5. The switch facilitates the selection of a suitable coupling method to provide stable triggering in accordance with the type of trigger signal (DC, AC waveform, AC waveform superimposed on DC, and high frequency noise on a waveform).

The EXT DC provides the input signal coupling for external sweep. In this case, however, HF REJ cannot be used generally.

EXT DC

As illustrated in Fig. 2-5, external trigger signal (or external sweep input when the instrument is used as an X-Y oscilloscope) is directly connected to the trigger circuit. Therefore, the triggering from the DC signal is enabled. If an external trigger signal is superimposed on the DC signal, and if the DC level exceeds the control range of the LEVEL control, the signal cannot be triggered.

For internal triggering (INT NORM, INT CH 2 ONLY), the DC component of the trigger signal has already been blocked. Therefore, the signal cannot be DC coupled even in this range.

AC

As shown in Fig. 2-5, the trigger signal is connected to the trigger generator through capacitor coupling. The DC component in the trigger signal is blocked and only the AC component is used for triggering. This ensures stable triggering by eliminating the influence of the DC component. The AC coupling is convenient for conventional measurement purposes, however triggering sensitivity decreases at low frequencies (below 10 Hz) and triggering becomes less stable.

HF REJ

In this position, the trigger signal is fed to the trigger generator through a low-pass filter, as shown in Fig. 2-5. High frequency signals (above approximately 10 kHz), or high frequency noise superimposed on the trigger signal, is bypassed. This coupling mode is convenient when using a trigger signal containing high frequency noise.

SLOPE

The SLOPE switch is used to select the positive (+) or negative (-) going triggering. The starting point of triggering can be selected with LEVEL (& AUTO) switch. (Refer to Fig. 2-6.)

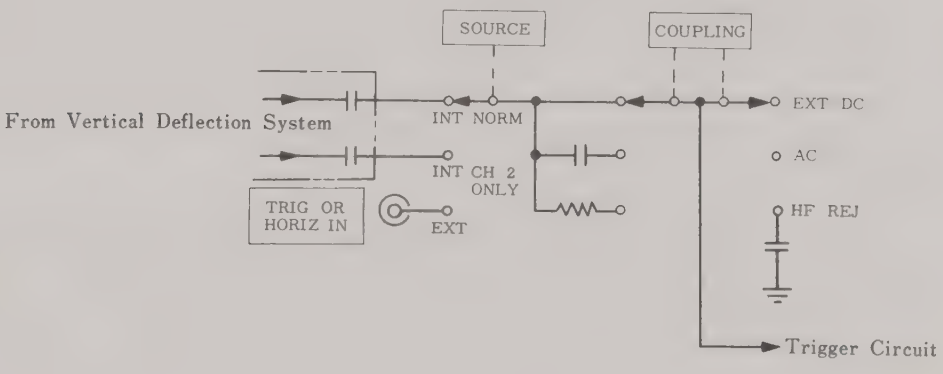


Fig. 2-5

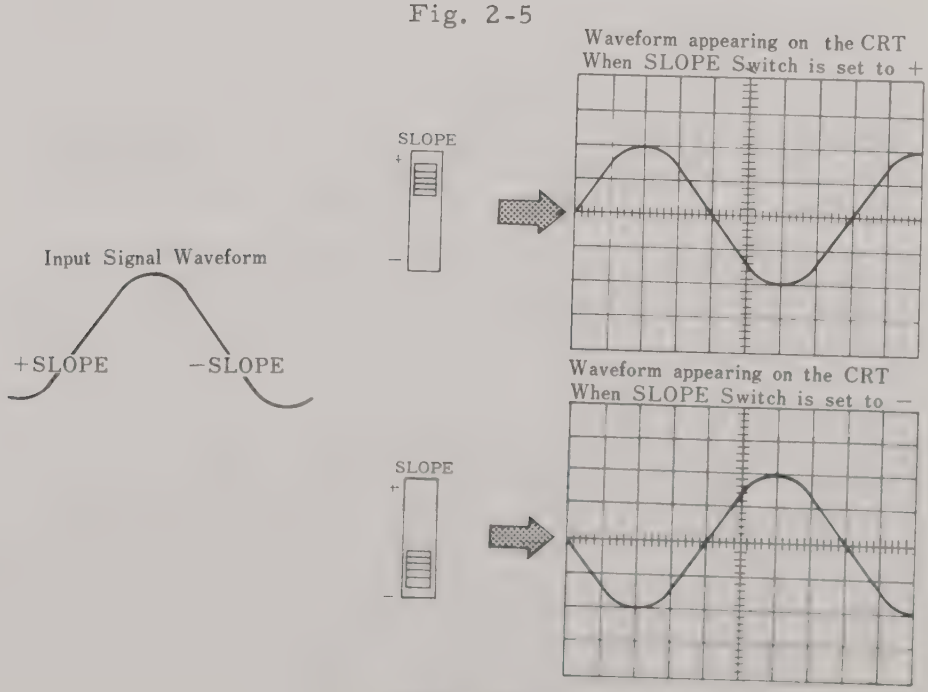


Fig. 2-6

Triggering Method (Auto Trigger)

Set the switches as follows:

SLOPE	+
COUPLING	AC
SOURCE	INT NORM

The preceding control settings enable automatic triggering upon connection of the input signal since the LEVEL (& AUTO) control is set to the AUTO position. With this setting, the triggering operation is simplified.

If the input signal level does not reach the triggering point, or it is 50 Hz or less, or in the absence of the input signal, the display will be freerun mode instead of triggering.

If the input signal is lower than 50 Hz, change the triggering mode to the NORMAL TRIGGER described below.

Triggering Method (Normal Trigger)

Rotate the LEVEL (& AUTO) control clockwise slowly. Then, operate the SLOPE control as shown in Fig. 2-7. How the controls SLOPE and LEVEL are related will be understood. The variable range of the triggering point of this instrument is 10 to 90 % of the slope height. (For an internally triggered sine wave of approximately 1 kHz with a vertical amplitude of 4 cm on the graticule --- the triggering range in the external trigger mode differs with the external trigger signal level.)

(It is difficult to observe the variable range of the trigger point on the graticule for sine wave, since this instrument does not contain a signal delay cable for the vertical deflection system.)

FREERUN

When confirmation of the ground potential for the vertical axis is required during measurement, depress the FREERUN button. As long as the button is being depressed, the sweep mode becomes FREERUN, regardless of presence of the input signal. If no input signal is applied, only a single trace will appear on the graticule. If any input is present, the waveform will be freerun instead of triggering.

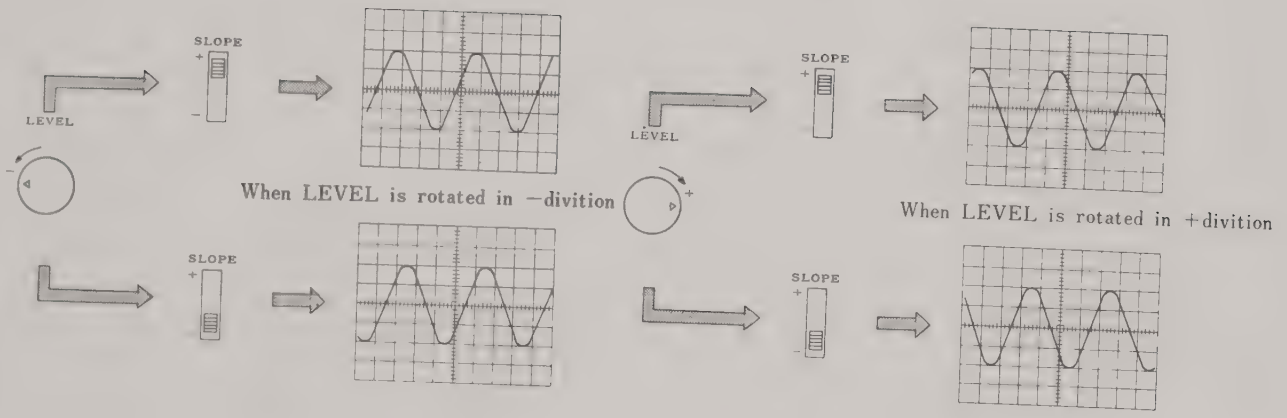


Fig. 2-7 LEVEL with Respect to SLOPE

Dual Trace Operation

First, place the MODE switch in the ALTER position. Then set the LEVEL (& AUTO) to AUTO and the TIME/CM to 2 mSEC position. When the POSITION control of CH 1 is turned to its mechanical midpoint, a calibrating voltage waveform and a sweep will appear on CH 1 and CH 2, respectively, as a result of the operation instructed in the previous paragraph. Then, set the AC-GND-DC switch to DC position, and connect the calibrating voltage to the input signal connector on CH 2 through another BNC cable furnished. Dual trace should now be observed on the CRT.

As the SOURCE is set to the INT NORM position, triggering will become unstable if the traces from CH 1 and CH 2 are shifted by adjusting the POSITION control. Then, place the SOURCE switch in the INT CH 2 ONLY position. Stable triggering can be provided by using a trigger signal derived from the input signal on CH 2 only.

Next, turn the TIME/CM control counterclockwise. Simultaneous viewing of both traces is unabled because CH 1 and CH 2 are alternatively swept. Therefore, simultaneous viewing of a low frequency input signal should be performed in the CHOP mode as stated below.

Now, place the MODE switch to CHOP position. Even if the sweep speed is lowered, simultaneous observation of both channels can be provided. Contrary to the ALTER mode, however, the trace may become a dotted line when the sweep speed is set higher (TIME/CM switch set to approximately 50 microseconds or more) making the observation difficult. Therefore, dual trace observation of high frequency signal should be performed in the ALTER mode. Trigger control is performed similar to that of the ALTER mode, except that the COUPLING is set to the HF REJ position.

In this way, dual trace operation can be provided in all TIME/CM ranges upon proper selection of the ALTER or CHOP mode.

Sweep Magnification

When a magnified display, with regard to time, of a particular part of a waveform is desired, the sweep speed may be increased. However, magnification by increasing sweep speed may drive the desired part out of the viewing area, unless the part is very close to the starting point of the sweep.

By pulling the POSITION (PULL X5 MAG) switch, the center portion of the display is magnified by 5 times, as shown in Fig. 2-8. The trace length in the viewing area is approximately 10 cm, however, the

unmagnified trace is now extended by 50 cm. The entire trace can be observed by rotating the POSITION control.

The sweep time, when magnified, is 1/5 of the switch position indication, and the maximum sweep time of 0.5 μsec/cm for an unmagnified trace, becomes 0.5 μsec/cm x 1/5 = 0.1 μsec/cm.

Magnification of the sweep with the POSITION (PULL X5 MAG) switch is advantageous for increasing the maximum sweep speed, but it reduces the sweep intensity and may cause confusion in calculating the time relation of the displayed waveform (the multiplication by 1/5 may be overlooked). It may be advisable not to use the magnified sweep except in the following cases.

(1) To magnify a particular point of the waveform which is a considerable distance from the starting point of the sweep.

(2) When a sweep speed higher than 0.5 μsec/cm is desired.

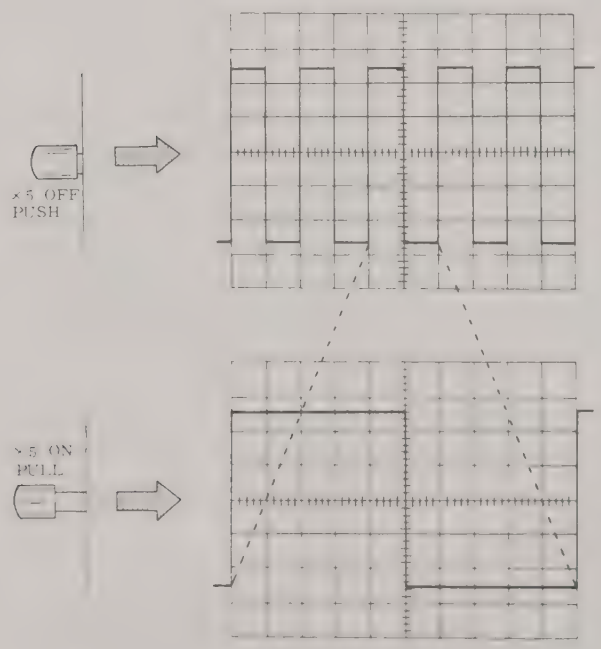


Fig. 2-8 Sweep Magnification with MAG Switch

X-Y Scope Operation

The basic operating procedure for X-Y scope measurements will be described, using the calibration signal as the input. First, place the controls in the positions indicated below.

INTENSITY	Rotate clockwise
MODE	CH 1
TIME/CM (& EXT HORIZ)	EXT HORIZ
SOURCE	EXT
COUPLING	EXT DC (or AC)
LEVEL (& AUTO)	LEVEL

After setting the switches and controls as stated above, rotate the vertical and horizontal POSITION controls so that a spot may appear at the center of the CRT.

Connect the CAL OUT 0.4 V and CH 1 INPUT connectors with the lead furnished. Connect the CAL OUT 0.4 V and TRIG OR HORIZ IN similarly. Set the VOLTS/CM of CH 1 to 0.2 V/cm range. Two spots should appear on a diagonal of the viewing area. This is a Lissajous figure showing a frequency ratio of 1:1 and a phase difference of zero.

Various Lissajous patterns will be displayed on the viewing area by feeding signals having different frequencies or different phase angles. (See Fig. 3-18.)

Various measurement procedures and their application will be described in this chapter.

Refer to Chapters 1 and 2, for technical characteristics and basic operating procedures of this instrument.

Connection of Input Signal 3-1
Calibration of Probe Phase 3-5
Voltage Measurement 3-6
Current Waveform Measurement 3-9
Time Measurement 3-9
Frequency Measurement 3-13
Phase Measurement 3-16
Measurement of Non-Electrical Phenomena 3-19

Connection of Input Signal

The input impedance of this synchroscope as viewed from the INPUT connector is 1 megohm (resistive component) shunted by 40 pF (capacitive component). When the furnished probe (attenuation ratio 10 : 1) is used, the resistive component increases to 10 megohms, while the capacitance component decreases to approximately 14 pF which largely reduces influence on the circuit under measurement.

The synchroscope can be connected to the signal source through various connection methods; the most common methods being conventional insulated cable, shielded cable, probe, and coaxial cable. The connecting method must be properly determined with reference to the following conditions:

Output impedance of the signal source
Magnitude and frequency of input signal
Magnetic induction from external circuits
Distance to the circuit to be measured

The proper connection methods can be classified in accordance with the type of input signal as shown in Table 3-1.

Table 3-1

Type of Input Signal \ Connecting Method			Insulated Cable	Shielded Cable	Probe	Coaxial Cable	Others
Low Frequency	Low Impedance	Near	O	O	O		
		Distant		O		O	
	High Impedance	Near		O	O		
		Distant		O			
High Frequency	Low Impedance	Near			O	O	
		Distant				O	
	High Impedance	Near			O	O	
		Distant					O

Individual connection methods are described as follows.

Input Connection Using Insulated Cable

In this method, the insulation is removed from both ends of the cable and the conductor is connected to the INPUT connector (conductor is secured to the INPUT through the insulated adapter --- BNC-BP-12D --- inserted in the INPUT connector) and the circuit under measurement. This method is simple and advantageous because the input signal is not attenuated.

However, if the cable is excessively long, or a magnetic field is present adjacent to the input circuit, magnetically inducted signals will be picked up causing interference with the measurement. The induction of noise component is particularly obvious when the output impedance of the input signal source is high.

Also, the stray capacitance of the input cable to ground is considerably large, and the total input capacitance of the synchroscope becomes (stray capacitance Cs) + (input capacitance of the synchroscope Co). The large input capacitance considerably influences the measuring circuit, as compared to a case using the probe.

For example, assuming the output impedance of the measured circuit is 1 kilohm, frequency of the input signal is 1 MHz, and the input capacitance (sum of the stray capacitance and input capacitance of the synchroscope) is 100 pF, and impedance of 1.6 kilohms is connected in parallel to the measured circuit. The influence of input capacitance, however, becomes negligible, when frequency of the input signal is considerably low, for example, the impedance becomes 1.6 megohms at 1 kHz.

This method using an insulated cable is suitable for measurement of low output impedance and low-frequency signals.

Input Connection Using a Shielded Cable

The induction of external noise can be prevented by using a shielded cable as the signal input cable, although the capacitance of the conductor to shield is considerably high, approximately 50 to 100 pF/m. Shielded cable is not suitable for measurement of high-frequency signals.

The shielded cable is advantageous in rejecting the influence of static induction noise.

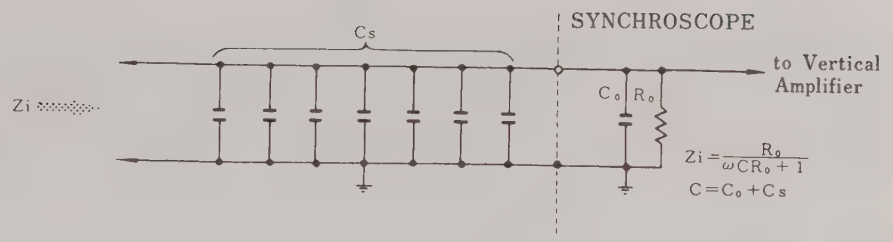


Fig. 3-1 Input Impedance When an Insulated Cable is Used

Input Connection Using a Probe

The cable of the attached probe (attenuation ratio 10 : 1) is entirely shielded as shown in Fig. 3-2, and use of the probe completely prevents the induction of external noise. Further a wideband attenuator is formed by the attenuation resistor Rp, parallel capacitor Cp, Input resistance Ro and its output capacitance Co, facilitating accurate measurement of high output impedance, and high-frequency input signals.

The input capacitance of the probe, as viewed from the probe tip, is approximately 14 pF, thus, the input impedance becomes considerably high, or approximately 11 kilohms at 1 MHz. Use of the probe is disadvantageous in the attenuation of an input signal --- since the signal is attenuated to 1/10 --- and cable length is limited to the length provided.

Input Connection Using a Coaxial Cable

When the output impedance of the signal source is 50, 75, 93 or 125 ohms, the input signal can be measured without causing attenuation up to the high-frequency region, by using a coaxial cable whose characteristic impedance is matched to the output impedance and properly matches terminal impedance of the measuring circuit. It should be noted that impedance of the circuit must be matched properly at the input connector of the synchroscope as shown in Fig. 3-3, otherwise, distortion will occur in the high-frequency signal waveform.

Other Methods

When a high-frequency, high-impedance signal source is considerably distant from the synchroscope, the signal can be properly transmitted and measured by using an impedance converter which converts the signal source impedance to the line impedance and a coaxial cable matched to the line impedance (75 ohms for example). A transformer may be used for impedance conversion of narrow-band signals, but a cathode follower or similar device must be used for impedance conversion of wideband signals. (Refer to Fig. 3-4.)

If high magnitude is available from the signal source, the signal may be transmitted, voltage-divided, and impedance-matched by the voltage-divider resistors as shown in Fig. 3-5.

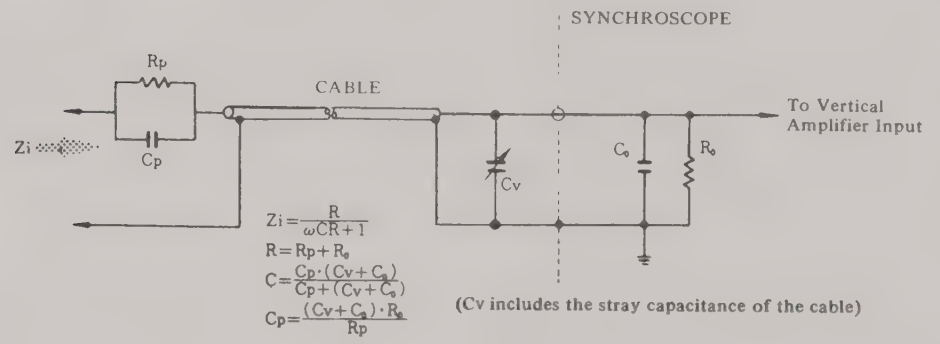


Fig. 3-2 Input Impedance When a Probe is Used

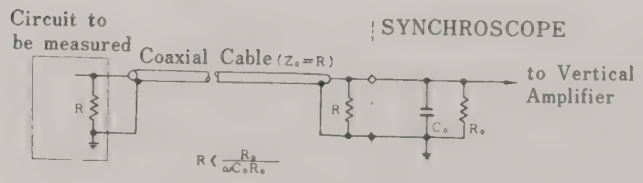


Fig. 3-3 Signal Transmission Using a Coaxial Cable

Calibration of Probe Phase

When the probe is used for measurement, the phase of the probe must be correctly adjusted, otherwise, accuracy of the displayed waveform will be lost. The probe phase may change if it is subjected to shock, hence it is necessary to check the phase when performing a measurement.

The probe phase calibration can be accomplished as follows: Set the VOLTS/CM to the 10 mV range and connect the probe tip to the CAL OUT 0.4 V connector. Adjust the output voltage so that the amplitude of the trace on the screen is approximately 4 cm. Then loosen the variable ceramic capacitor located on the probe by using a screwdriver for probe adjustment. Rotate this part in either direction and set it correctly observing the waveform of which the leading edge will vary as shown in Fig. 3-7.

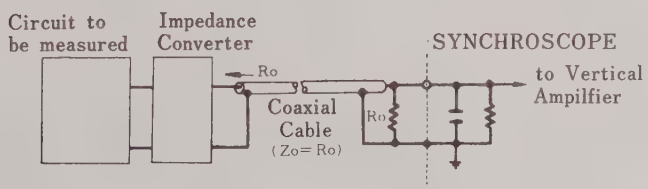


Fig. 3-4 Long-Distance Transmission of Signal (1)

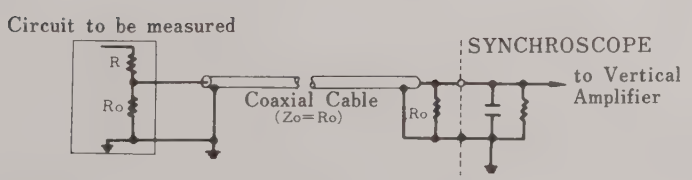


Fig. 3-5 Long-Distance Transmission of Signal (2)

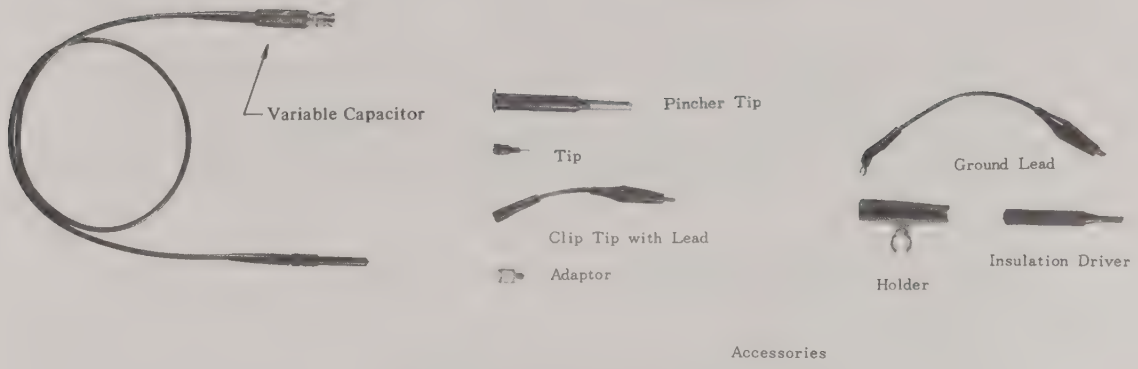


Fig. 3-6 Probe

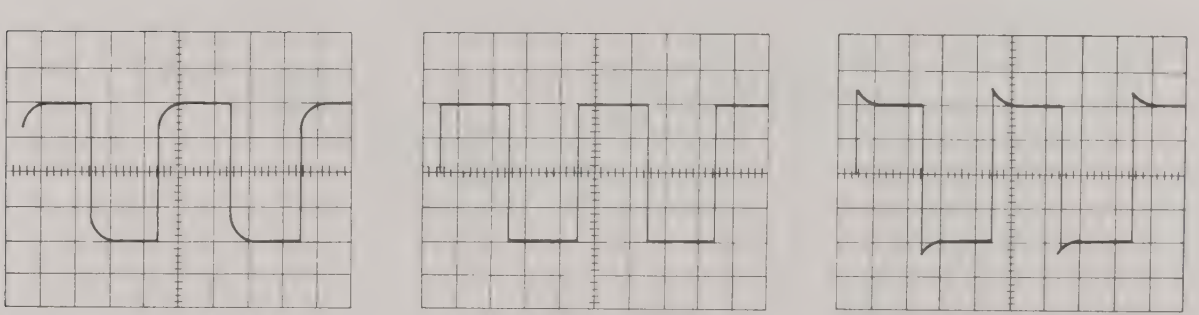


Fig. 3-7 Trimmer Adjustment
and Output Waveforms

Voltage Measurement

Quantitative Measurement

For direct reading of voltage values in quantitative measurements, the VARIABLE control must be turned fully clockwise. However, quantitative measurement of waveform amplitude is also possible with the VARIABLE control in the other position in the following method.

(1) Read the vertical amplitude of input signal on the graticule.

(2) Connect the calibration voltage (CAL OUT) to the INPUT instead of the above signal while the VOLTS/CM switch and the VARIABLE control should be placed in the same positions as of (1). The vertical deflection sensitivity at these control positions is then calculated from the following equation (3-1).

$$\text{Vertical deflection sensitivity (V/cm)} = \frac{\text{Indication of CALIBRATOR VOLTS switch (V)}}{\text{Displayed amplitude of CALIB voltage (cm)}} \quad \ldots\ldots (3\text{-}1)$$

The signal amplitude is calculated from the following equation (3-2).

$$\text{Input signal voltage (V)} = \text{Vertical deflection sensitivity (V/cm)} \times \text{displayed amplitude (cm)} \quad \ldots\ldots (3\text{-}2)$$

The calibrating voltages (CAL OUT) for this instrument are 0.4 V and 0.04 V. When other calibrating voltages are used, apply a specified voltage to the INPUT connector and calculate from the equations (3-1) and (3-2).

DC Voltage Measurement

This instrument can also be used as a DC voltmeter. First, obtain a trace in the free run mode and select a fast sweep time so that the trace will appear steady.

Set the AC-GND-DC switch to GND. The trace which appears when no input signal is applied is used as the reference line (0 V) for DC voltage measurement. See Fig. 3-8. First, set this reference line at any position which will afford easy reading. Set the AC-GND-DC switch to DC position, and touch the test lead to the measuring point. This should cause the trace to move. Read the displacement on the graticule. If the trace goes beyond the viewing area at this moment, switch the VOLTS/CM to another appropriate position to bring it in an easily visible position on the CRT.

When the signal level is displayed above the zero level, the polarity of the input signal is positive (+), and a negative (-) voltage is displayed below the zero level line. Letting the distance between the two lines represent A (cm), the input voltage can be calculated as in equation (3-3) or (3-4).

When the 10 : 1 probe is used;

$$\text{Voltage (V)} = \text{VOLTS/CM switch value (V/CM)} \times \text{displacement of trace level (cm)} \times 10 \quad \ldots\ldots \quad (3\text{-}3)$$

When the input signal is directly connected to the input connector for measurement;

$$\text{Voltage (V)} = \text{VOLTS/CM switch value (V/cm)} \times \text{displacement of trace level (cm)} \quad \ldots\ldots\ldots \quad (3\text{-}4)$$

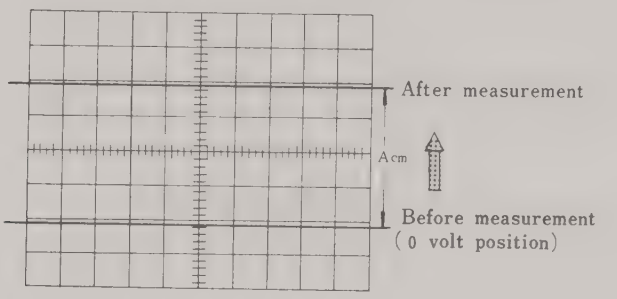


Fig. 3-8 DC Voltage Measurement

AC Voltage Measurement

When the signal to be measured is superimposed on DC and the DC component is greater in amplitude than the AC component as shown in Fig. 3-9 with the AC-GND-DC switch at DC position, some portion of the AC component may be displayed beyond the viewing area. The AC waveform can be returned to the viewing area of the graticule by adjusting the POSITION control, but this may result in erroneous measurements. The AC portion may also be measured by switching the VOLTS/CM control, but this reduces the accuracy of the measurement.

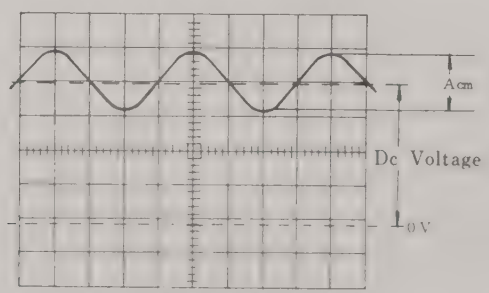


Fig. 3-9 AC Signal Superimposed on DC Voltage

In such a case, set the AC-GND-DC switch to AC. In this way, only the AC component will be displayed since the DC component is blocked by the capacitor. Suppose the amplitude of the AC component is A cm; the rms value can then be calculated by the equation (3-3) or (3-4). (It should be noted that the displayed amplitude of an AC signal is attenuated by 3 dB at approx. 3 Hz in the AC mode. When the probe is used, the attenuation is 3 dB at approx. 0.3 Hz.)

The AC signal amplitude calculated from equations (3-3) and (3-4) represent the peak-to-peak value, and the effective value (V rms) of a sine wave is found as:

$$\text{Effective voltage (V rms)} = \frac{\text{Volt (p-p)}}{2\sqrt{2}} \quad \ldots\ldots\ldots\ldots\ldots \quad (3\text{-}5)$$

Current Waveform Measurement

CRT oscilloscopes, including synchroscopes, display only the voltage of given signals. Electrical phenomena other than voltage, and mechanical vibrations or other physical phenomena must be converted into voltage variations before they are connected to the INPUT.

Current can be measured by reading the voltage drop across a resistor of known value inserted in the circuit being measured by using a synchroscope. The current is then calculated with Ohm's law, E=IR. The value of a resistor inserted in the circuit must be sufficiently small so as not to change the characteristics of the circuit being measured.

Time Measurement

Measurement of Time Interval

The time interval between two optional points on a waveform can be read directly by the horizontal distance between the points from the graticule with the indication of TIME/CM switch, while setting the VARIABLE control to the CALIB position.

Set the VARIABLE control to the CALIB position. Trigger the display and set the TIME/CM switch to a position which facilitates reading of the distance as shown in Fig. 3-10. The time interval (T) between the two points is calculated from equation (3-6).

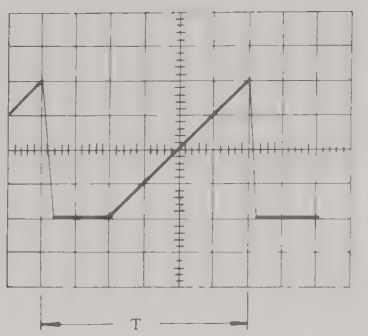


Fig. 3-10 Time Interval Measurement

T (sec) = TIME/CM switch value (sec/cm)
x distance between the points on the graticule (cm)
x reciprocal of MAG switch value .....(3-6)

The reciprocal of the MAG switch value is 1 when the display is not magnified and 0.2 when magnified.

Difference of Time between Two Signals

The time difference between two signals is easily measured by using the ALTER or CHOP mode of this instrument. First set the SOURCE to INT CH 2 ONLY and connect the leading input signal (a) to CH 2 INPUT connector and the lagging signal (b) to CH 1 INPUT connector. When these signals are triggered, a waveform shown in Fig. 3-11 appears. Read the distance T from the graticule, and calculate the time from equation (3-6).

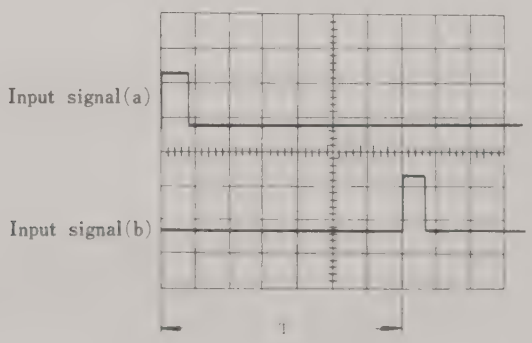
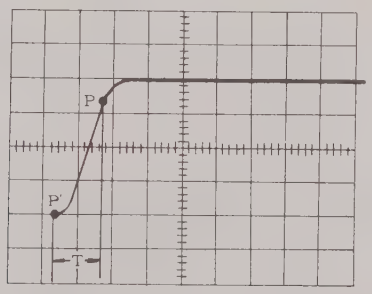


Fig. 3-11 Time Difference Measurement in ALTER or CHOP Mode

Measurement of Leading (or Falling) Edge of Waveform

Since the signal delay cable is not provided in the vertical amplifier, observation of the leading edge of the fast rising signal or falling edge of the fast falling signal becomes difficult. If the signal is faster than the input signal (approx. 150 nsec), connect it to the TRIG OR HORIZ. The display in this case must be externally triggered. See Fig. 3-12.



In the absence of the delay cable, sweep starts at point P' and when the delay cable is incorporated, sweep atarts at point P. In this case, apply the external trigger signal faster than the input signal by $P' - P = T$.

Fig. 3-12

Pulse Width Measurement

Pulse width is measured as follows.

Adjust the vertical position and amplitude of the display so that the pulse height is equal both above and below the center horizontal line of the graticule (set total height to 2 cm or 4 cm). Turn the VARIABLE control fully clockwise and set the TIME/CM switch to a position which allows easiest reading of the display. Read the distance (T) between the centers of the leading and the falling edges, (or cross-points of these edges and the center horizontal line) from the scale on the horizontal graticule line as shown in Fig. 3-13. The pulse width is calculated from equation (3-6). Magnify the horizontal display if the pulse width is very narrow.

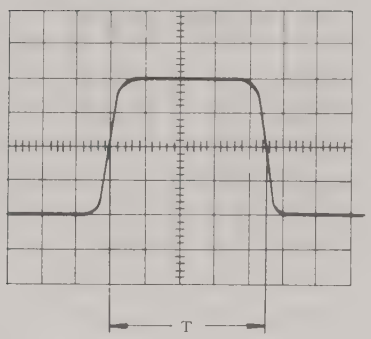


Fig. 3-13 Pulse Width Measurement

Measurement of Rise (or Fall) Time of Pulse

Set the vertical and horizontal position and amplitude controls as in the pulse width measurement. As indicated in Fig. 3-14, move the pulse display horizontally so that the upper 10 % (4 mm in the example, since the pulse height is 4 cm) of the leading edge crosses the vertical center line of the graticule, and read the distance (T_1) between the point where the vertical leading (or falling) edge of the pulse crosses the horizontal center line, and the vertical center line of the graticule.

Adjust the POSITION control to move the lower 10 % of the leading edge so that it crosses the vertical center line. Read the distance T_2. Substitute the value $T_1 + T_2$ in equation (3-6) to obtain the pulse rise time T (sec).

Direct reading of the pulse rise time is possible only when the rise (or fall) time of the pulse is sufficiently slower than the rise time of this instrument, i. e. 70 nsec. If a pulse having a very fast rise time is measured, the result (T) obtained from equation (3-6) must be corrected by the following equation (3-7).

$$Tr = \sqrt{T^2 - Ts^2} \quad \text{..... (3-7)}$$

where Tr: True value of pulse width
T : Measured value
Ts: Rise time of this instrument (70 nsec)

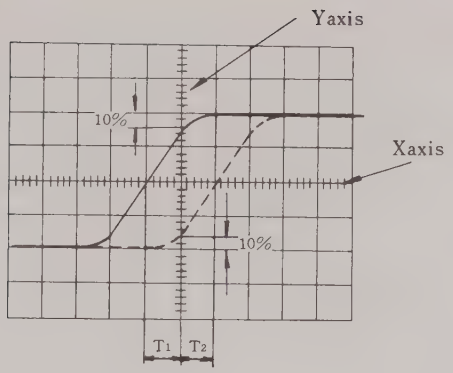


Fig. 3-14 Rise (or Fall) Time Measurement

Frequency Measurement

Frequency measurements can be largely classified into three types.

First, the frequency can be calculated from the time per cycle (equation 3-6) obtained as shown in Fig. 3-15, and equation (3-8).

$$\text{Frequency } f(\text{Hz}) = \frac{1}{\text{Period } T \text{ (sec)}} \quad \cdots\cdots\cdots\cdots\cdots\cdots (3\text{-}8)$$

In Fig. 3-15, the length of one cycle is 8 cm and the TIME/CM switch is in the 1 μsec/cm position. Thus, the period T is;

$$T \text{ (sec)} = 8 \text{ cm} \times 1 \ \mu\text{sec/cm} = 8 \ \mu\text{sec}$$

Therefore, the frequency f(Hz) is;

$$f(\text{Hz}) = \frac{1}{8 \times 10^{-6} \text{ sec}} = 125 \times 10^{3} \text{ (Hz)} = 125 \text{ kHz}$$

Second, the frequency can be calculated from equation (3-9) by counting the number of cycles (N) displayed in the horizontal scale (10 cm) as shown in Fig. 3-16.

$$\text{Frequency } f(\text{Hz}) = \frac{N}{\text{TIME/CM switch value} \times 10} \quad \cdots\cdots\cdots (3\text{-}9)$$

This method is more accurate than the former method, and absolute accuracy of measurement approaches that of sweep time, provided that the number of cycles, N, is sufficiently large (30 to 50). When N is comparatively small, reading the value of N below the decimal point becomes uncertain, and accuracy decreases.

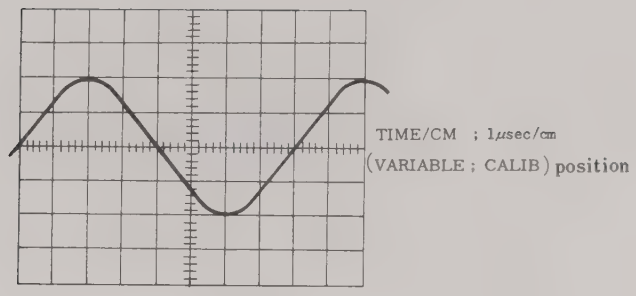


Fig. 3-15 Frequency Measurement (1)

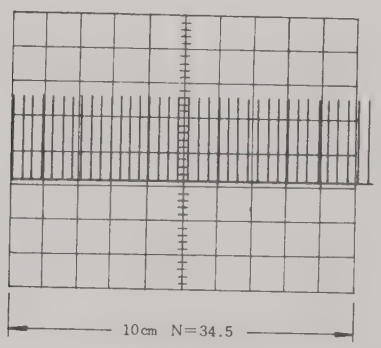


Fig. 3-16 Frequency Measurement (2)

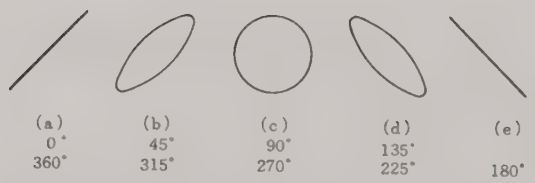


Fig. 3-17 Lissajous Pattern of Sine Wave

These frequency measurement methods are based upon time measurement. When the frequency of the waveform to be measured is comparatively low (below 100 kHz) and its waveform is a simple sine, square, triangular, or sawtooth, the frequency may be measured by using the instrument as an XY scope to display a Lissajous pattern, as described in Chapter 2.

Set the TIME/CM (& EXT HORIZ) to the EXT HORIZ, and the SOURCE to the EXT positions. Then set the SOURCE switch to either EXT DC or AC according to the input signal. The spot will be displayed. Feed the signal to be measured (assumed to be a sine wave) to CH 1 INPUT and connect the TRIG OR HORIZ IN to a signal source of a known frequency (calibrated signal generator). Set both the vertical and horizontal amplitudes to approximately 4 cm.

Vary the signal generator frequency to obtain a Lissajous pattern for a frequency ratio of 1 : 1, as shown in Fig. 3-17. The Lissajous pattern for 1 : 1 is either a circle, ellipse, or a straight line. When the frequency ratio approaches 1 : 1, the pattern continuously varies from a → b → c → d → e → d → c → b → a, and repeats this variation. As the frequency ratio becomes closer to 1 : 1, the above variation subsides, and finally the pattern stops varying and one of the below waveforms will be displayed.

The signal generator frequency at which the pattern becomes stable represents the frequency of the signal being measured, and the accuracy of the measurement is equal to that of the signal generator.

The number of pattern variation cycles per second, (from "a" to "a") represents the difference between the two frequencies. The approximate relation of the measured frequency to the standard frequency --- lower or higher than the standard --- can be easily determined by slightly changing the signal generator frequency. These events dictate that frequency measurements using a Lissajous pattern must be carried out for a sufficiently long period, particularly for low frequencies, (for example 1 Hz or 10 Hz) to confirm that the pattern will not vary in this period.

Lissajous patterns for sine wave signals connected to CH 1 TRIG OR HORIZ IN connectors having different frequency ratios are shown in Fig. 3-18. The pattern for an optional frequency ratio may be determined by geometric drawings, however, the 1 : 1 pattern method using a variable frequency signal generator is the simplest and most accurate. Fig. 3-19 shows the Lissajous pattern for different waveforms.

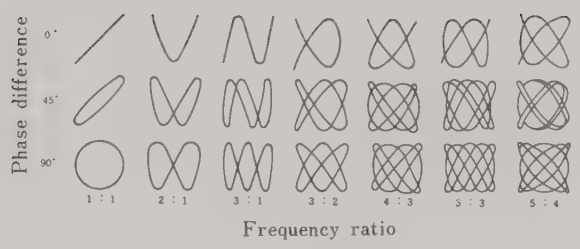


Fig. 3-18 Lissajous Patterns for Various Frequency Ratios

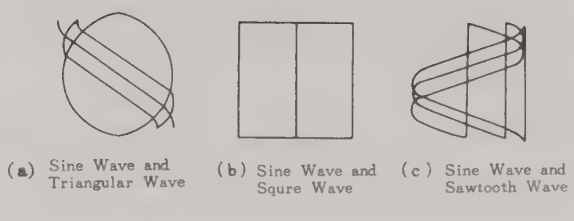


Fig. 3-19 Lissajous Patterns for Different Waveform (Frequency Ratio 1:1)

Phase Measurement

Measurement with Lissajous Pattern

Phase difference between two signals can be calculated from equation (3-10) obtained from the Lissajous pattern as the XY scope (Refer to Fig. 3-20).

$$\text{Phase difference angle} = \sin^{-1}\frac{A}{B} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3\text{-}10)$$

This method is, however, restricted to frequencies below 10 kHz due to phase distortion in the instrument at higher frequencies.

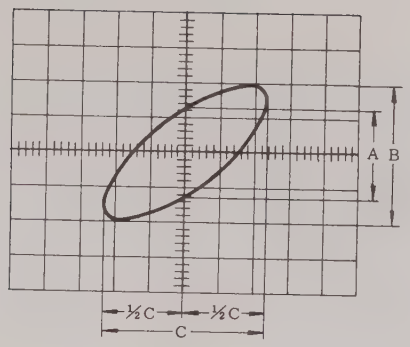


Fig. 3-20 Phase Measurement
with Lissajous Pattern

Phase Measurement by Dual-Trace Operation
(when the two frequencies are equal)

Fig. 3-21 shows an example of a phase difference measurement between two sine waves (leading and lagging)

For this method, the TIME/CM switch and the VARIABLE control (horizontal) are set so that one cycle of the signal is displayed in exactly 9 cm. One vertical division (1 cm) represents 40 degrees --- since one cycle = 2 π = 360 degrees --- and the phase difference between the signals is calculated by equation (3-11).

Phase difference (degree) = Horizontal distance between the two signals on the graticule (T) x 40 degrees ..... (3-11)

Dual-Trace Measurement of Signals of Different Frequencies

Fig. 3-22 shows an example of a pulse shaper output of synchroscope and a sawtooth wave triggered by this pulse. To measure the phase difference of two signals having different frequencies (provided the frequency ratio is an integer), the sweep must be triggered by connecting the lower frequency signal. If the sweep is triggered by the higher frequency signal (square wave in this example), the sawtooth wave signals will not be triggered properly.

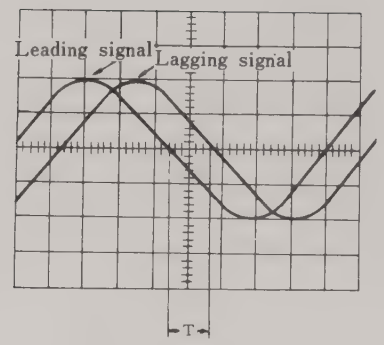


Fig. 3-21 Phase Measurement of Two Signals of the Same Frequency

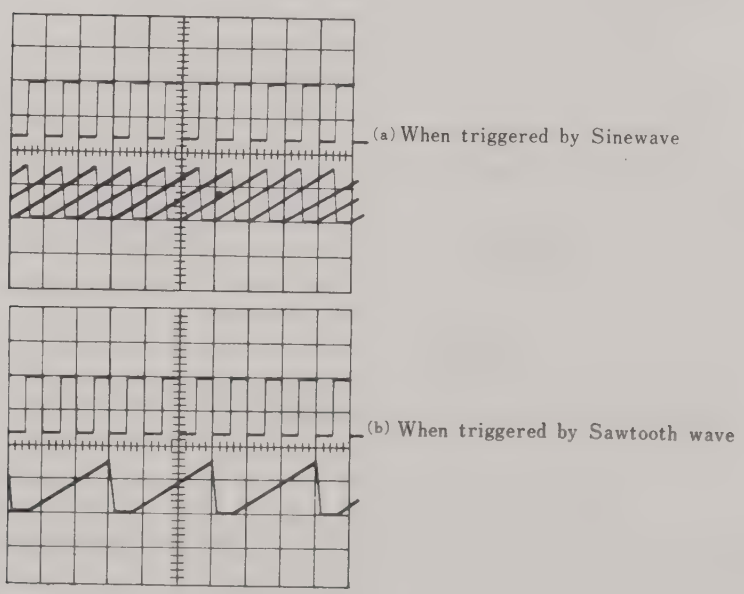


Fig. 3-22 Phase Measurement of Two Signals of Different Frequencies

Measurement of Non-Electrical Phenomena

Voltage is the only phenomenon which can be measured directly, on a synchroscope. Synchroscopes, however, are widely used for measuring phenomena other than voltage as a result of the development of transducers which convert these phenomena into voltage. Transducer type measurements are now practiced in various fields such as displacement, distortion, pressure, and vibration, etc.

A summary of typical transducers will be described in the following paragraphs.

Measurement of Kinetic Variation

The following properties of material under external force are employed to convert kinetic variations such as displacement, distortion, pressure, or vibration, into electrical variations.

(1) Resistance variations of wire resistors and semiconductors due to externally applied force. These devices are known as strain gages.

(2) Piezoelectric elements such as quarts crystals or barium titanate which produce an electrical output proportional to an externally applied force.

(3) Capacitance pickup that varies its internal capacitance in accordance with an externally applied force.

(4) Ferromagnetic pickup which varies its magnetic properties with external force.

(5) Electromagnetic pickup that converts displacement into electromagnetic force.

Various other types of transducers are also produced. All these transducers are attached either directly or through an adequate material to the object being measured.

These transducers may be classified according to their purpose, such as distortion, pressure, or vibration measurement, etc. These devices can be further classified into types which operate at high temperature or humidity, high frequency, large amplitude vibration, and those which are extremely sensitive to minute vibrations, etc.

Various new transducers are being developed, and additional applications are expected.

Optical and Temperature Measurement

Transducers which convert light variations into electrical variations are commonly known as photoelectric cells and phototransistors. Photomultiplier tubes are used for detecting very dim or minute changes of light.

Thermistors, of which electrical resistance varies with temperature, and thermocouples composed of two metallic wires (copper and constantan wires) which generate an electromotive force when their junction point is heated, are the most commonly used thermal transducers.

The operation of individual circuits will be described in this chapter to aid in the maintenance and calibration of this instrument.

The overall operation will be described first, using the block diagram in Fig. 4-1. A detailed description of individual circuit operation follows.

General 4-1
Circuit Description 4-3
- Vertical Amplifier 4-3
- CH1 Preamplifier 4-3
- CH2 Preamplifier 4-5
- Switching Circuit 4-6
- Main Amplifier 4-9
- Trigger Generator 4-9
- Sawtooth Generator 4-16
- Horizontal Amplifier 4-21
- Z Axis Amplifier 4-22
- CRT Circuit 4-23
- Power Supply 4-25
- Calibrator 4-27

Operation Theory

The circuit configuration of this instrument is shown in Fig. 4-1. Each block operates with a final purpose of deflecting the electron beam of the CRT.

Two independent preamplifiers are used for the vertical deflection system. Operation of these preamplifiers can be optionally selected by electronic switching system. The input signal applied to the INPUT connector is converted to a balanced signal and amplified at the pre-amplifier, and fed to the switching circuit.

By opening or closing this diode gate with the signal from the switching circuit either or both balanced signals from CH 1 and/or CH 2 are fed to the main amplifier. In other words, the MODE switch selects either CH 1 or CH 2, or two signals electronically switched (ALT or CHOP).

The main amplifier functions to amplify the balanced signal up to a sufficient level to deflect the electron beam of the CRT. A portion of the input signal from the main amplifier is separated as the trigger signal for INT NORM mode (for both CH 1 and CH 2). A portion of the input signal fed to the CH 2 INPUT connector is separated as the trigger signal for INT CH 2 (for CH 2 only).

By switching the SOURCE switch, any of the trigger signal described above or externally triggered signal fed to the TRIG OR HORIZ IN is fed to the trigger circuit. At the trigger circuit, the trigger pulse having a constant rise time and amplitude is generated by the trigger signal.

The sawtooth wave generating circuit triggered by this trigger signal to generate sawtooth waves. Freerun oscillation of the sawtooth wave generator is effected by depressing the PUSH FREERUN button. The sawtooth wave is amplified at the horizontal amplifier and fed to the vertical deflection plate for deflecting the electron beam in the horizontal direction.

For external triggering, the input signal externally fed to the TRIG OR HORIZ IN connector is applied to the horizontal amplifier through a part of trigger circuit. Similarly to the sawtooth wave signal, this input signal is amplified for deflecting the electron beam.

The Z-axis amplifier amplifies the unblanking pulses from the sawtooth wave generator, chop blanking pulses from the switching circuit,

and external intensity modulation input signal from the Z AXIS INPUT connector. The amplifier also outputs a voltage determined by the INTENSITY control. The amplified signals and voltage are fed to the grid of the CRT to control the intensity of the trace.

The CRT circuit produces the high voltage required to emit and accelerate the electron beam.

The calibrator circuit produces square waves for checking the vertical deflection sensitivity and for calibrating the voltage probe.

The low voltage power circuit provides low voltage power for operating each circuit in Fig. 4-1.

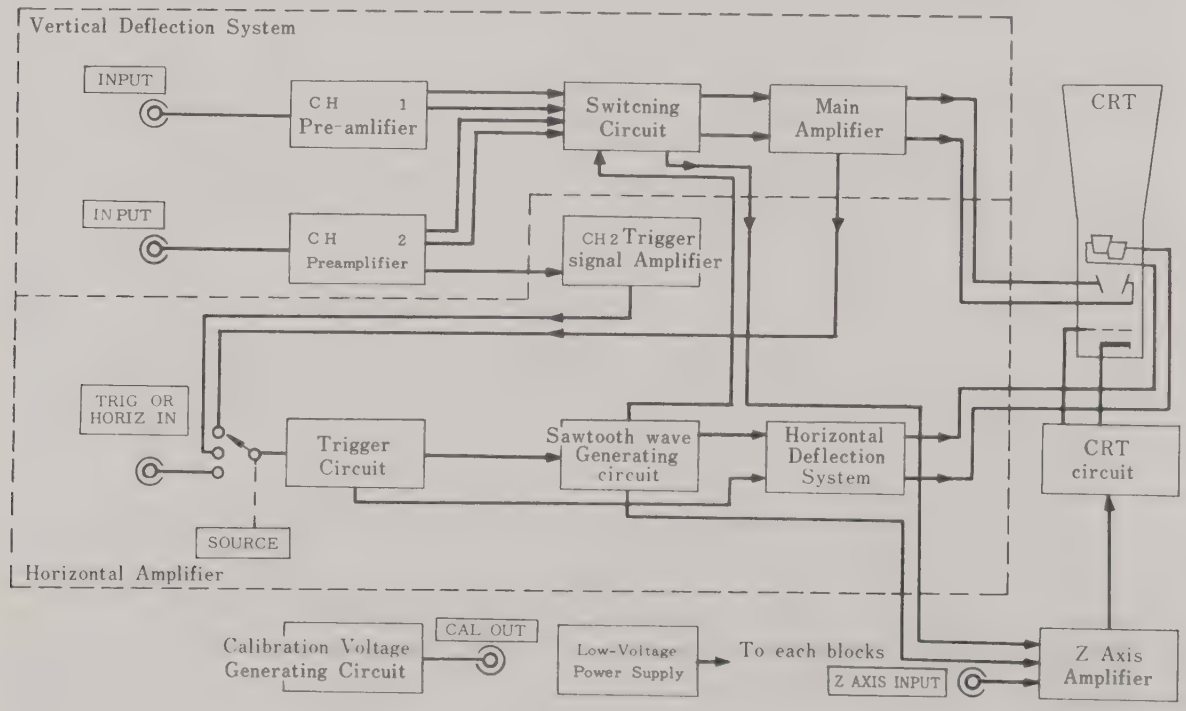


Fig. 4-1 Basic Block Diagram

CIRCUIT DESCRIPTION

The individual circuit operation will be described using the block and circuit diagrams as references.

Similar circuits (i. e. CH1 and CH2 preamplifiers) will be collectively described, and any differences between the two circuits will be explained.

Vertical Amplifier

CH1 Preamplifier

The configuration of the CH1 preamplifier is shown in Fig. 4-2.

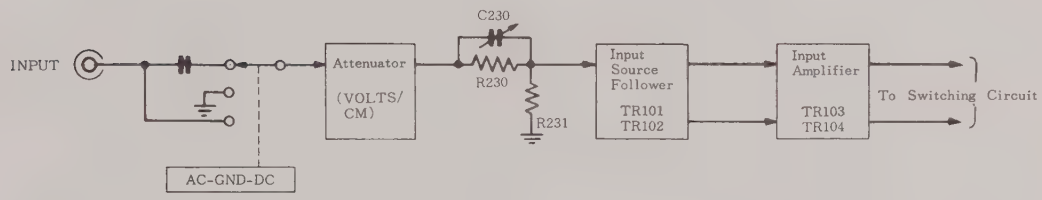


Fig. 4-2 CH1 Preamplifier Block Diagram

Input Signal Coupling

The signal connected to the INPUT connector is fed to the input attenuator through the AC-GND-DC switch. In the AC position of the switch, capacitor C101 (C111 for CH2) blocks the input signal DC component and allows only the AC component to pass, while in the DC position, the input signal is fed directly to the input attenuator. The GND position of the switch opens the signal path and grounds the attenuator input. This position is provided to ground the amplifier input when it is desired to determine ground reference potential without disconnecting the signal from the INPUT connector.

Attenuator Detail

The input attenuator attenuates the input signal before it is applied to the input source follower. This parallel capacitance

compensated resistive attenuator consists of five components (÷2, ÷5, ÷ 10, ÷ 100, ÷1000) providing a combination of 10 ranges available at the VOLTS/CM switch. The input signal is fed through this attenuator and an attenuator composed of R230, C230, R231, where the input signal is attenuated by 9/10. This attenuator protects the FET (junction type field effect transistor) input source follower from an excessive input signal.

The input resistance, viewed from the INPUT side, is retained at 1 Megohm at all attenuator positions.

Input Source Follower

A junction type FET (field effect transistor), TR101, forms the input source follower circuit providing a high input impedance to reduce loading on the circuit to be measured. The output impedance is reduced to drive the succeeding amplifier stage.

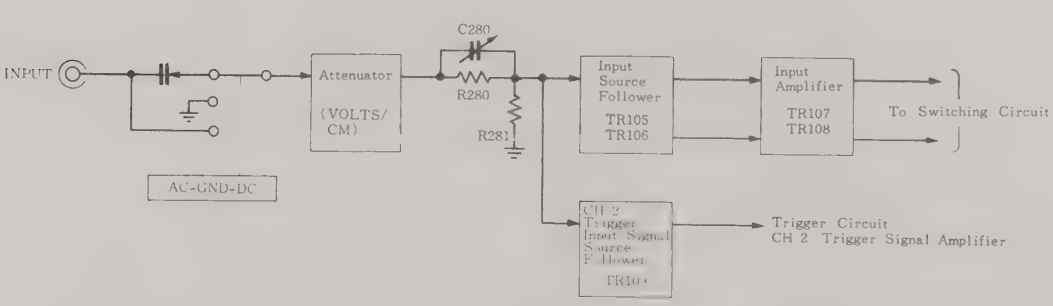


Fig. 4-3 CH1 Preamplifier Block Diagram

Diodes D101 and D102 function to prevent damage to TR101 due to an excessively large input signal. The output of TR101 is fed to the base of the following amplifier, TR103. TR102 source is connected to the base of input amplifier TR104 providing input amplifier balance. TR102 is paralleled with TR101 in order to minimize thermal drift of the amplifier.

Input Amplifier

The input signal applied to the base of TR103 is a balanced output (opposite polarity) obtained from the collectors of input amplifiers TR103 and TR104.

Table 4-1 Attenuation Range and Combination

VOLTS/CM Ranges	Attenuator Combination
10 mV	------
20	÷ 2
50	÷ 5
.1 V	÷ 10,
.2	÷ 10, ÷ 2
.5	÷ 10, ÷ 5
1	÷ 100
2	÷ 100, ÷ 2
5	÷ 100, ÷ 5
10	÷ 1000

R114 (CHI GAIN) is a variable resistor for calibrating the deflection sensitivity of CHI. R115 is a variable resistor which continuously adjusts the sensitivity of each range of the VOLTS/CM switch.

The variable resistor R111 DC BAL is connected to TR102 gate to provide a balanced DC potential at TR103 and TR104 collectors during sensitivity control with R115. The vertical position can be shifted by varying the collector potential with R119 POSITION.

CH2 Preamplifier

The CH2 preamplifier employs the circuit configuration shown in Fig. 4-3. The configuration is identical to that of the CH1 preamplifier except for the CH2 trigger signal source follower.

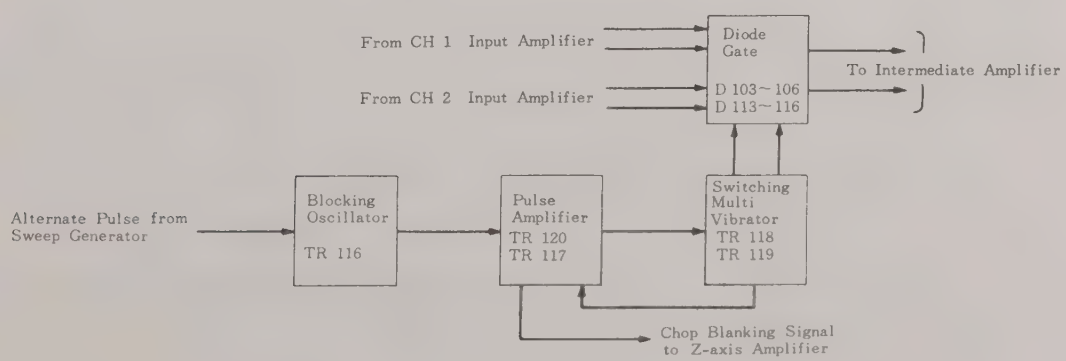


Fig. 4-4 Switching Circuit Block Diagram

CH2 Trigger Signal Input Source Follower

The CH2 trigger signal input source follower employs a junction type field effect transistor TR109. The input signal is applied to the gate and the low impedance output is taken from the source as the CH2 single trigger signal.

This field effect transistor is connected in parallel with TR105. TR109 is protected from excessively large input signals in a similar manner to the CH1 input source follower.

Switching Circuit

The switching circuit configuration is shown in Fig. 4-4. The switching multi-vibrator (described later) and diode gate connect the CH1 and CH2 preamplifier balanced outputs to the main amplifier.

Blocking Oscillator

Blocking oscillator TR116 produces pulses with a repetition rate of approximately 100 kHz when the MODE switch is set in the CHOP position, in order to effect electronic switching of the CH1 and CH2 sweeps.

When the MODE switch is set to the ALTER position, TR116 functions as a monostable blocked oscillator triggered with alternate pulses from the sweep generator. Blocked oscillation is caused every time the alternate pulse is applied, producing pulses for switching the CH1 and CH2 sweeps.

CHOP mode operation will now be described. When the MODE switch is set in the CHOP position, +10 V is connected to TR116 emitter through R171, R172, and R194, and collector current begins to flow. Now, suppose current has just started to flow. The collector coil T101, induces a voltage across the coil connected to the base causing its potential to rise, resulting in more collector current and so on until saturation is reached. At this moment, the induced voltage across the base coil disappears since there is no longer any change in collector current causing the collector current to decrease. This change, in turn, induces a voltage across the base coil causing the base potential to further decrease causing the collector current to cut off.

Since collector current no longer flows, the voltage induced in the base coil disappears and the cycle repeats itself. (Collector currents start to flow again.)

In this manner, TR116 produces pulses of 100 kHz or more.

When the MODE switch is set to the ALTER position, the emitter of TR116 is grounded through R171. The base is grounded through T101 and collector current will not flow. At this time, positive alternate pulses are applied to the emitter of TR116 through C190. This positive pulse allows the collector current to flow through the collector coil of T101. This induces a voltage across the base coil causing the base potential to rise, resulting in more collector current and so on until saturation is reached. Subsequent operation is as described for the CHOP mode; the initial status where no collector current flows is stable and blocked oscillation is caused every time the alternate pulse is applied.

Pulse Amplifier

The output of the blocking oscillator when the MODE switch is set to the CHOP or ALTER position is connected to the base of TR120. TR120 is an emitter follower and drives the base of TR117 with a low impedance source. When the MODE switch is set to the CHOP position, the signal is also fed to the Z-axis amplifier as the chop blanking signal.

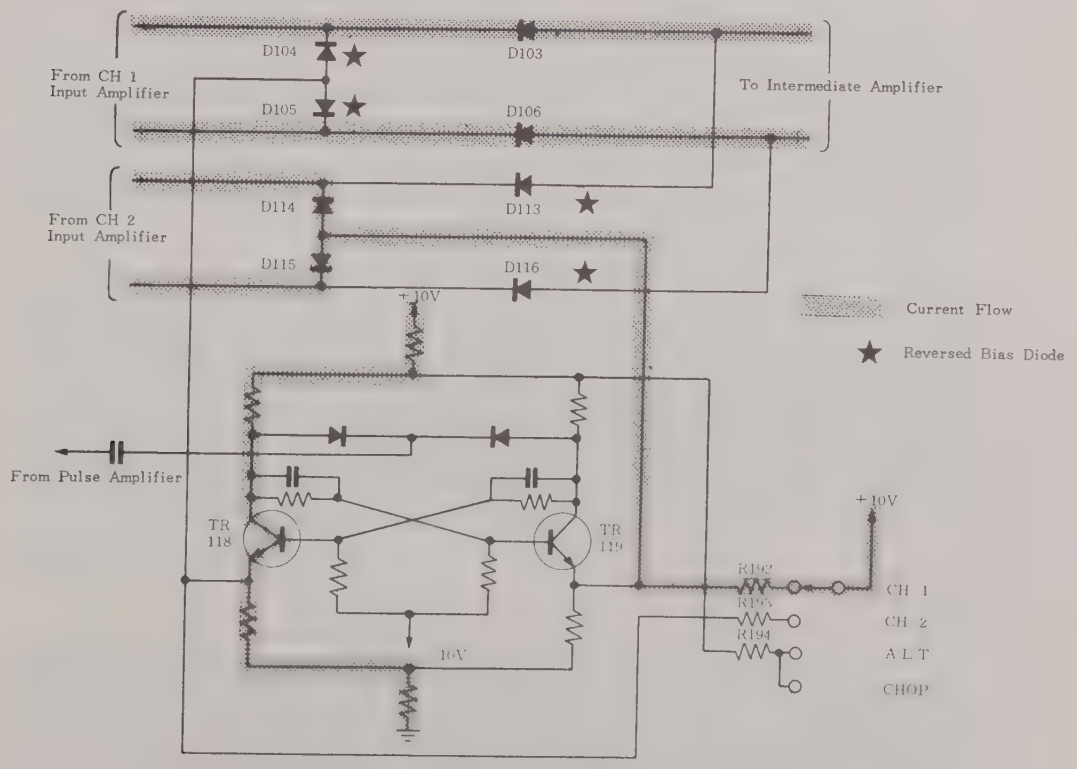


Fig. 4-5 Diode Gate Operation (in CH1 position)

The CHOP or ALTER signals connected to the base of TR117 are amplified and inverted, then sent to the switching multivibrator.

Switching Multivibrator

The switching multivibrator operates as a bi-stable multivibrator, generating signals for opening and closing the diode gate in accordance with the MODE switch position.

CH 1

When the MODE switch is set to the CH1 position, +10 V is applied to the emitter of TR119 through R192, causing TR119 to turn off and TR118 to turn on. At this time, the emitter potential of TR119 is higher than that of TR118. Therefore, D114 and D115 are forward biased and conduct, allowing current to flow as illustrated in Fig. 4-5. On the other hand, D104 and D105 are reverse biased and D103 and D106 are forward biased allowing current to flow as shown in Fig. 4-5. In this manner, only the CH1 input amplifier balanced output is sent to the succeeding amplifier.

CH2

When the MODE switch is set to the CH2 position, +10 V is connected to the emitter of TR118 through R193, causing TR118 to turn off and TR119 to conduct. The emitter potential of the TR118 becomes higher than that of TR119. Therefore, the diode gate operation is reversed with respect to that of CH1, and only the CH2 input amplifier balanced signal is connected to the succeeding amplifier.

ALTER

In the ALTER mode, +10 V is connected through R194 and the switching multivibrator operates as a bi-stable multivibrator. The signal is triggered by the alternate pulse supplied from the pulse amplifier, thereby repeating on and off operation. In this manner, the diode gate repeats on/off operation connecting the balanced signals of CH1 and CH2 alternately to the succeeding amplifier.

CHOP

In the CHOP mode, the switching multivibrator also operates as a bi-stable multivibrator. Triggering is effected by the 100 kHz chop signal supplied by the pulse amplifier. The triggered output of the switching multivibrator functions to switch the diode gate, as in the

case of the ALT mode, thereby connecting the CH1 and CH2 input amplifier balanced signals alternately to the succeeding amplifier.

Main Amplifier

The main amplifier circuit configuration is as shown in Fig. 4-6.

Intermediate Amplifier

The balanced signal supplied through the input amplifier and diode gate is further amplified by TR110 and TR111, and sent from their collectors to the output amplifier as the balanced signal. A part of the signal from TR110 collector is also fed to the triggering circuit through C150 as the CH1 and CH2 internal trigger signal. C151 and R146 placed between the collectors of TR110 and TR111 are used to obtain better high frequency characteristics.

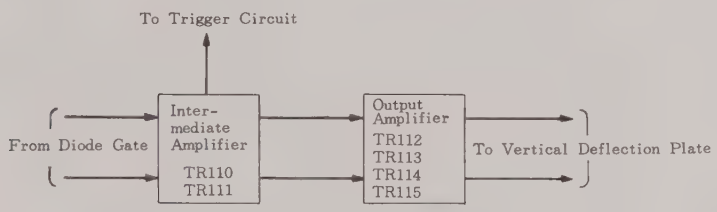


Fig. 4-6 Main Amplifier Block Diagram

Output Amplifier

The output amplifier amplifies the balanced signal to a level sufficient to deflect the CRT electron beam. The output amplifier consists of TR112. TR113 and TR114. TR115, and form a negative feedback circuit for improved frequency response characteristics. TR114. TR115 obtains the output signal from the emitter of TR112 and TR113 and also functions as TR112 and TR113 load. D107ab and D108ab are used to connect TR112. TR113 and TR114. TR115.

Trigger Generator

The trigger generator circuit configuration is as shown in Fig. 4-7. The generator produces a pulse output to trigger the sweep generator. The trigger pulse is formed by a part of the input signal branched from the vertical deflection system (internal trigger signal obtained at INT NORM, INT CH2 ONLY) or the external trigger

signal applied to the TRIG OR HORIZ IN.

A part of the external signal supplied to the TRIG OR HORIZ IN when external triggering is used is applied to the horizontal amplifier.

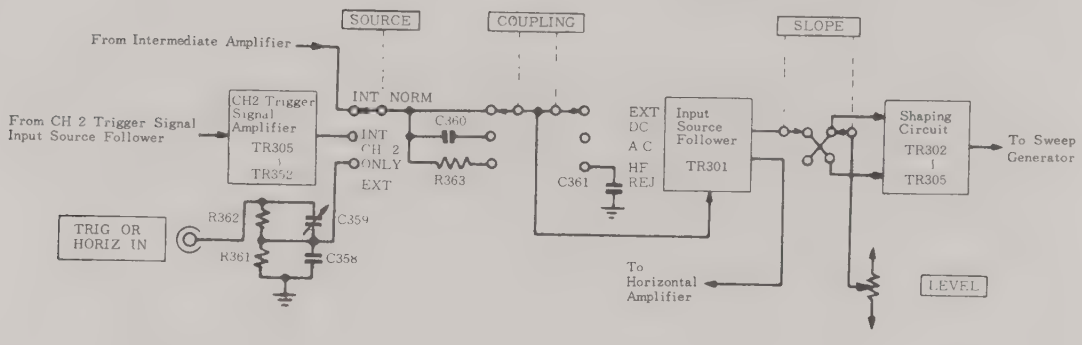


Fig. 4-7 Trigger Generator Block Diagram

CH2 Trigger Signal Amplifier

The trigger signal from the CH2 preamplifier is applied to the emitter follower TR350, and is amplified by TR351 and TR352, which function as the CH2 internal trigger signal amplifier. A part of the trigger signal is fed back to TR351 from TR352 to improve the frequency response characteristics.

Trigger Signal Selection

The SOURCE switch selects the trigger signal source from the external or internal signal.

This switch is used to select the CH1 and CH2 common trigger signals from the vertical deflection system intermediate amplifier or the trigger signal from the CH2 trigger signal amplifier in INT CH2 ONLY.

When the external trigger signal is used, the trigger signal is attenuated to approximately 1/5 by the attenuator composed of R362, C359, R361, and C358.

Trigger Signal Input Coupling Selection

The COUPLING switch selects the coupling mode between the trigger signal and the input source follower. In the EXT DC position, the external trigger signals fed from TRIG OR HORIZ IN are coupled directly to the trigger generator input. With the internal trigger signal (INT NORM, INT CH2 ONLY), however, the input signal DC components have been already blocked by a capacitor. In the AC position, capacitor C360 is inserted in series with the input circuit to block the input signal DC components now allowing low frequency trigger signals (lower than approximately 10 Hz) to pass.

The low-pass filter in the HF REJ position is composed of R363 and C361. This filter attenuates high frequency components and noise in the trigger signal and allows only low frequency trigger signals (from approximately 10 Hz to 10 kHz) to pass.

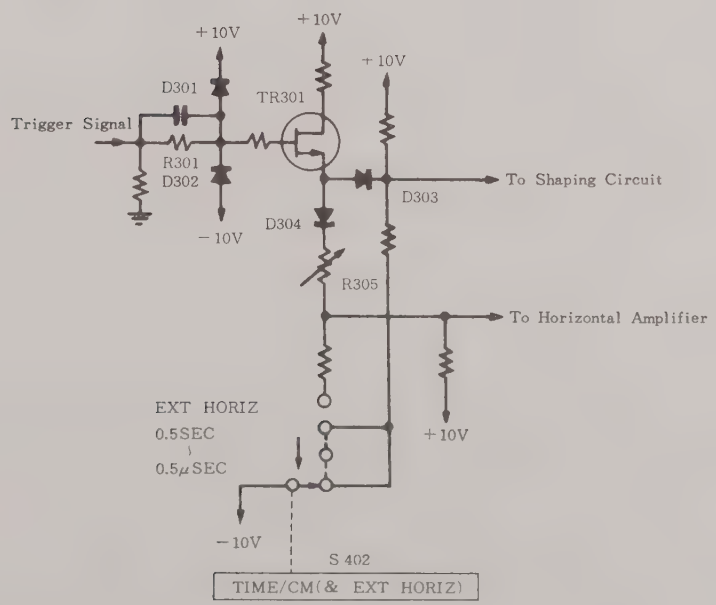


Fig. 4-8 Input Source Follower

Input Source Follower

The input source follower circuit configuration is as shown in Fig. 4-8. An FET (field effect transistor) is used for the input source follower which provides a high input impedance and a low output impedance. Limiter diodes D301, D302, and R301 protect the FET from excessively large input signals. When an excessively large input signal is applied from the external trigger signal source, the FET is protected by an attenuating circuit composed of R362, C359, R361, and C358.

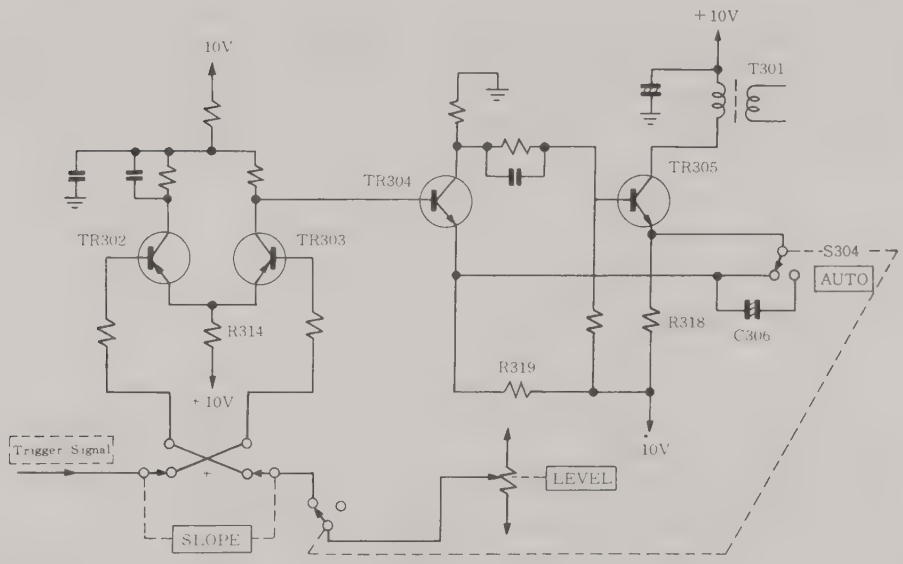


Fig. 4-9 Pulse Shaper Circuit

The circuit from TRIG OR HORIZ IN to the source follower is used as the input circuit in external triggering. (The usual coupling mode HF REJ cannot be used in this case.)

For external triggering, D303 is turned off and D304 on by switching the TIME/CM switch to the EXT HORIZ position and the input signal is applied to the horizontal amplifier. The operation is reversed for other triggering modes (other than external triggering), and the trigger signal is applied to the pulse shaper.

R305 is used to control the horizontal amplifier DC potential when the input signal is varied by R631 during external triggering.

Pulse Shaper

The pulse shaper circuit is composed of differential amplifier (TR302. TR303) and a schmitt multivibrator (TR304. TR305), as illustrated in Fig. 4-9.

Differential Amplifier

TR302 and TR303 are connected at their emitters and to a positive voltage of 10 V through R314. This allows TR302 and TR303 to differentially operate; when the collector current of one increases, that of the other decreases, and vice versa.

For example, when the base potential of TR302 decreases with respect to that of TR303, the collector current of TR302 increases and that of TR303 decreases.

For simplicity explanation will be made on the assumption that either TR302 or TR303 turns on whenever its collector current exceeds that of the other, and that the remaining turns transistor off. In actual operation, however, a certain time lag exists in the increase or decrease in collector current. Refer to Fig. 4-10.

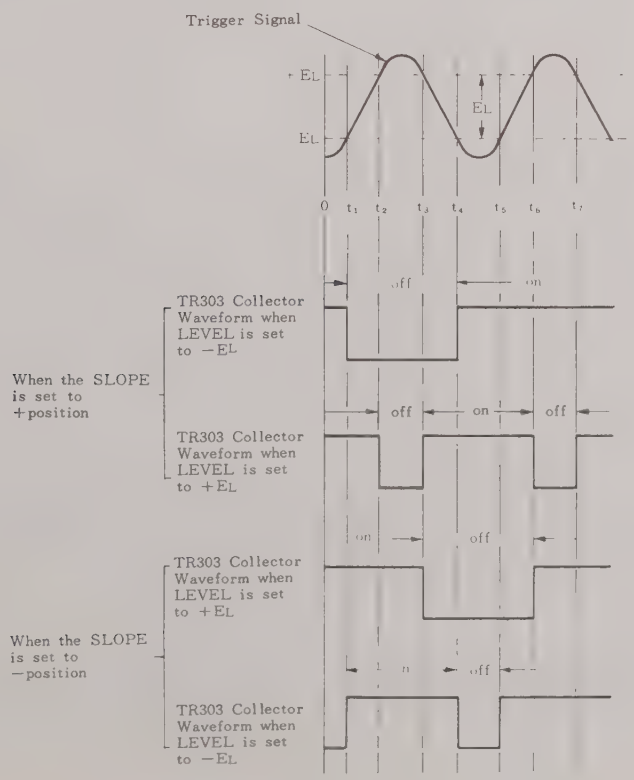


Fig. 4-10 Relationship between the Trigger Signal and TR303 Operation

SLOPE Switch + and LEVEL - :

Assuming that the SLOPE switch is set to the + position, a trigger signal from the input source follower is supplied to the base of TR303, and a variable voltage is supplied to the base of TR302 with the LEVEL control. As shown in Fig. 4-10, when the sine-wave trigger signal is fed to the base of TR303 and the level-adjusted voltage -EL is supplied from the LEVEL control to the base of TR302, TR302 turns off and TR303 conducts at time t_0. When the sine-wave amplitude passes its peak value and becomes higher than -EL (t_1), TR303 turns off and TR302 conducts. When the sine-wave amplitude passes the positive peak and becomes lower than -EL (t_2), TR302 is shut off and TR303 conducts, and the circuit returns to the initial state.

SLOPE Switch + and LEVEL + :

When the voltage controlled by LEVEL is set to +EL, and leaving the SLOPE switch in the + position, the trigger signal is supplied to the base of TR303 and the +EL voltage is connected to the base of TR302.

TR302 conducts and TR303 turns off when the positive-going sine-wave amplitude exceeds the +EL voltage (t_2). Then the sine wave passes its peak value and becomes lower than +EL (t_3), TR302 is shut off and TR303 conducts returning the circuit state to the initial condition.

SLOPE Switch - and LEVEL + :

By turning the SLOPE switch to -, the trigger signal is supplied to the base of TR302 and the level-controlled voltage with LEVEL is supplied to the base of TR303. When the trigger signal passes its peak value and becomes lower than +EL (t_3), TR302 conducts and TR303 is shut off. The circuit returns to the initial state when the trigger signal passes its negative peak value and become more positive than +EL. TR302 is shut off and TR303 conducts.

SLOPE Switch - and LEVEL - :

When a negative voltage -EL is supplied from the LEVEL control, leaving the SLOPE switch in the - position, TR302 conducts and TR303 is shut off the moment the trigger signal becomes more negative than -EL.

The circuit returns to the initial state when the trigger signal becomes more positive than -EL (t_5). TR302 is shut off and TR303 conducts.

By selecting polarity of the SLOPE switch and LEVEL voltage in these examples, the transition time of TR303 from on to off can be selected at an optional point on the trigger signal slope. The transition of TR303 drives the schmitt multivibrator in the subsequent stage to generate the trigger pulse. In this way, the display can be triggered at any point on the + or - slope of the input signal.

Schmitt Multivibrator.

Transistors TR304 and TR305 compose a schmitt multivibrator. Normally TR304 conducts turning TR305 off. (The transistor state may be reversed in accordance with the setting of the LEVEL control.)

The transition of TR303 from on to off causes TR304 to be shut off, and TR304 is kept shut off while TR303 is turning off. When TR303 turns on, TR304 also turns on causing TR305 to shut off. Square-wave signals having a constant rise time and amplitude are output from the collector of TR305. The square wave drives the pulse transformer T301 connected to the collector of TR305 to output the trigger pulse. The trigger pulse is generated in the differential amplifier to coincide with the transition time of TR303. (Refer to Fig. 4-10.)

AUTO Operation

By turning the LEVEL control fully counterclockwise, the switches S304 a and b are set to the AUTO position, and the schmitt multivibrator (TR304 and TR305), starts free oscillation at a repetition rate of less than 50 Hz which is determined with time constant C306, R318 and R319. The free oscillation continues until a trigger signal is fed from TR303, and trigger pulses of less than 50 Hz are output from the pulse transformer T301. When the trigger signal is supplied from TR303, TR304 and TR305 repeat reversal of state each time the pulse is supplied. In the AUTO mode, the trigger pulse is self-oscillated at a rate lower than 50 Hz when the trigger signal is not present, and the trigger pulse is synchronized with the trigger signal when the signal is supplied. Note that the trigger signal will not be synchronized to input trigger signals having a repetition slower than the time constant determined with C306, R318 and R319.

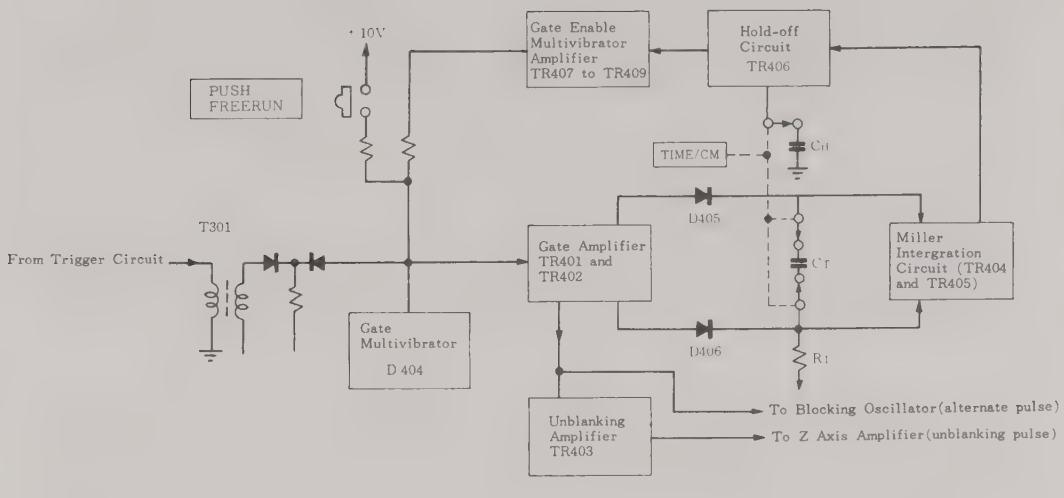


Fig. 4-11 Block Diagram of Sawtooth-Wave Generator

Sawtooth Generator

The configuration of the sawtooth generator is shown in Fig. 4-11. Free running sweep is actuated when the PUSH FREERUN switch is depressed, and the circuit is triggered with other switch settings to generate the following three types of signal.

(1) Sawtooth wave -- The positive sawtooth wave is fed to the horizontal amplifier to sweep the horizontal axis of the display.

(2) Unblanking signal -- The unblanking signal to intensify the trace and blank the retrace is fed from the unblanking amplifier to the Z axis amplifier, and finally to the control grid of the CRT.

(3) Alternate signal to actuate the alternate sweep -- Fed to the switching circuit in the vertical deflection system.

Sawtooth generator operation is summarized as follows.

The gate multivibrator is triggered by pulses from the trigger circuit, and shuts the disconnector diode D406 to actuate the Miller integrator. The disconnector diode D406 is normally conducting causing the Miller integrator to stop. When a trigger signal is given the multivibrator state is reversed, the disconnector diode D406 is shut off, and the Miller integrator generates a sawtooth wave.

The slope of voltage rise is determined by the CT and RT in the TIME/CM circuit. When the increasing voltage reaches a certain value, the gate enable multivibrator operates to reverse the multivibrator causing D406 to conduct to discharge the Miller integrator quickly. The rate of voltage drop is reduced in the hold-off circuit which gives a time delay C_H.

After the time delay, the gate multivibrator is reset through the gate enable multivibrator. One cycle of operation ends and a sawtooth wave is generated.

Trigger Sweep

Assume a condition before the sweep starts with no trigger signal. D404 is a gate tunnel diode whose operation characteristics are shown in Fig. 4-12. Ⓐ current flows through the diode setting its operating point to point A , and the diode is in the low-voltage region. Thus TR401 is shut off and its collector potential is set to a high voltage.

The base potential of TR402 is voltage divided by resistors R412 and R413, and is fixed to approximately +3 V. The high collector voltage of TR401 causes TR402 to turn on and sets its collector voltage at a high value. Thus, D406 conducts. TR404 and TR405 compose the Miller integrator. The source follower FET (Field-Effect Transistor) TR404 increases the input impedance of the Miller integrator to a sufficient value. D406, which is conducting, causes TR405 to conduct through TR404, and the collector voltage of TR405 is set to a lower potential. Since TR402 and TR405 are both conducting, diode D405 also clamps the collector voltage of TR405 to a constant level.

Emitter-follower TR406 sets D407 to off. The shutting transistor TR406 charges the hold-off capacitor C_H, through R431, to negative. In the other schmitt multivibrator, TR407 is shutting off and TR408 is conducting. TR408 causes TR409 to shut off. The high collector potential of TR409 supplies a current to the gate tunnel diode D404 through R442, and sets the operating point of the diode near to I_P(point A). (Refer to Fig. 4-12.)

When a positive trigger pulse is supplied from TR301, through D402, to the sawtooth generator which is in the stationary state, D403 conducts. The current previously flowing through R404 and R403 flows in diode D404. Thus the current through D404 exceeds I_P, and the operating point of the tunnel diode jumps from point Ⓐ in the low-voltage region to point Ⓑ in the high-voltage region and is stabilized at point Ⓒ. At the operating point, the trigger pulse cannot return the diode to the lower voltage region.

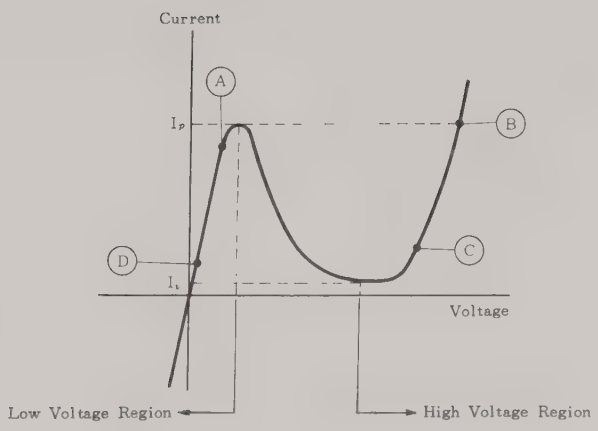


Fig. 4-12 Tunnel Diode Characteristics (D404)

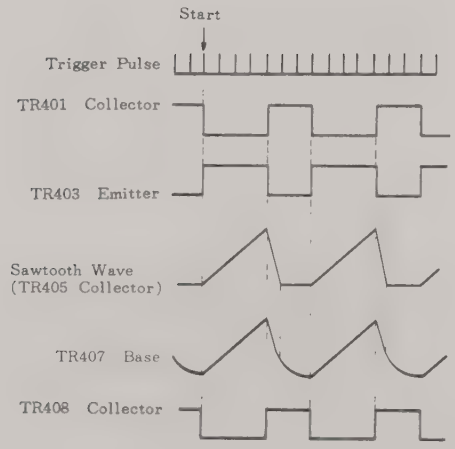


Fig. 4-13 Waveforms in Sawtooth Generator

The transition of tunnel diode turns TR401 on, and its collector voltage drops. Thus, TR402 is shut off, its collector potential becomes lower and diodes D405 and D406 are shut off. Through source follower TR404, TR405 also shut off. When the disconnecting diode D406 is shut off, the timing capacitor CT is charged through the timing resistor RT toward -10 V. The charging voltage is supplied to the base of the Miller integrator TR405.

Diode D410 conducts to clamp the anode voltage of D406 at approx. 0.7 V to prevent excessive reverse bias voltage and increase in leakage current at D406.

The negative charging voltage supplied through TR404 to the base of TR405 causes the collector voltage of TR405 to increase to a positive direction. The negative-feedback loop connecting the collector of TR405 through CT to the base of TR404 charges the timing capacitor CT at a constant current. A highly linear sawtooth wave is output from TR405.

As the sawtooth wave voltage increases at the base of emitter-follower TR406, the emitter voltage of TR406 also increases.

D407 is normally shut off, and the hold-off capacitor CH is charged to negative through R431. When the emitter potential of TR406 reaches a predetermined voltage, D407 turns on, and the negative charged capacitor CH starts to be charged toward positive up to the emitter voltage of TR406. The positive charging voltage is supplied to the base of TR407 in the schmitt circuit and causes TR407 to conduct. The conduction of TR407 causes TR408 to be shut off. The collector voltage of TR408 increases to conduct TR409.

The conduction of TR409 causes its collector current to flow thereby reducing the current flowing to tunnel diode D404 through R442. The tunnel diode jumps from point Ⓒ in the high-voltage region to point Ⓓ in the low-voltage region. (Refer to Fig. 4-12.)

While the tunnel diode is in this state, the trigger pulse cannot drive the tunnel diode to the high-voltage region. This change of D404 to the lower voltage region causes TR401 to shut off and TR402 and D406 to conduct.

The conduction of D406 quickly discharges the voltage in timing capacitor CT, and TR405 is shut off through TR404. The collector voltage of TR405 quickly drops, D405 conducts, and the base and emitter voltages of TR406 drop similarly causing D407 to shut off.

The shutting off of D407 charges the hold-off capacitor C_H, which has been charged positive with the emitter voltage of TR406,

gradually toward negative starting from -10 V. When the negative-going charge voltage reaches a predetermined level, D407 conducts and reverses the schmitt circuit. TR408 conducts and its collector voltage drops.

The time during which the holding capacitor C_H is gradually charged toward negative until it causes TR407 to conduct is called the hold-off time. The hold-off time must be sufficiently longer than the time it takes for the collector voltage of TR405 to restore to normal (retrace time). Proper hold-off time is determined by selecting the values of R431 and C_H.

When TR408 returns to conduct and its collector voltage becomes low, the base voltage of TR409 is also reduced and TR409 shuts off. The shutting off of TR409 changes the collector current to flow through R442 into the tunnel diode 404. The operating point of the tunnel diode returns to point Ⓐ which is placed close to I_P, and resets the diode to be ready for triggering.

One cycle of sawtooth-wave generation ends when the tunnel diode is reset, and the same operation cycle is repeated triggered by a succeeding trigger pulse.

The output sawtooth wave and waveforms in the circuit are shown in Fig. 4-13.

The variable resistor R403 (TRIG THRESHOLD) is adjusted so that the tunnel diode will be set to the triggered state and start to sweep when a trigger pulse is fed from T301, and the sweep circuit will stop while the trigger signal is not present.

Negative square pulses are output from the collector of TR401 through R451 to the vertical axis circuit. The pulses are used for the alternate signal in dual-trace switching.

The other negative pulse is output from the emitter of TR403 through R450. The pulse is sent to the Z axis amplifier to unblank the CRT. These negative pulses are generated whenever the sawtooth wave is generated.

Free-running Sweep

Depression of the PUSH FREERUN switch causes the tunnel diode D404, when it is set to the trigger ready condition, to jump from the low-voltage region to the high voltage region, because the switch supplies a positive current from the +10 V line through R443. The transition of the tunnel diode generates a sawtooth wave, and the

generator circuit operates to return the tunnel diode to the trigger ready condition, but the positive current supplies through R443 causes the tunnel diode to again jump from the low-voltage region to the high-voltage region, and the next sawtooth wave is generated. In this way, the sweep circuit continues free-run sweep, regardless of presence of the trigger signal, as long as the PUSH FREERUN switch is depressed.

Horizontal Amplifier

The circuit configuration of the horizontal amplifier is shown in Fig. 4-14. In accordance with the position of the TIME/CM (& EXT. HORIZ) switch, the circuit functions to amplify one of the following signals to an amplitude sufficient to deflect the electron beam of the CRT in the horizontal direction.

(1) Sawtooth wave from the sawtooth generator.

(2) Input signal connected to the TRIG or HORIZ IN, in external sweep operation.

Input Amplifier

An emitter-follower TR601 is used for the input amplifier to drive TR602 with very low circuit impedance. The signal supplied to the base of TR602 is amplified and fed to TR603. A negative feedback loop is formed between the collector of TR603 and the base of TR601, and a resistor in the loop is used for the X5 magnifier.

By pulling the PULL X5 switch, relay RL601 is energized with the +10 V supply, to ground one side of R603. The grounding of R603 reduces the amount of negative feedback from TR603 to TR601 and increases the amplification factor of this circuit by 5 times.

The POSITION control, R606, is used to change the base potential of TR601 and finally controls the electron beam position horizontally.

The variable resistor R601 (X5 MAG CENT) adjusts the voltage balance in the X5 magnifier circuit so that the display will be magnified by 5 times from the center of the CRT when the PULL X5 switch is operated. Capacitors C601 and C602 are high-frequency compensators. R610 (SWP CAL) controls the amplitude of the signal supplied from the sawtooth-wave generator. C606 compensates the high-frequency component of the sawtooth wave.

R633 (EXT HORIZ GAIN) controls external sweep sensitivity, while R631 reduces the amplitude of the external sweep input signal. TR603 is an emitter-follower which drives the subsequent amplifier stage with low impedance.

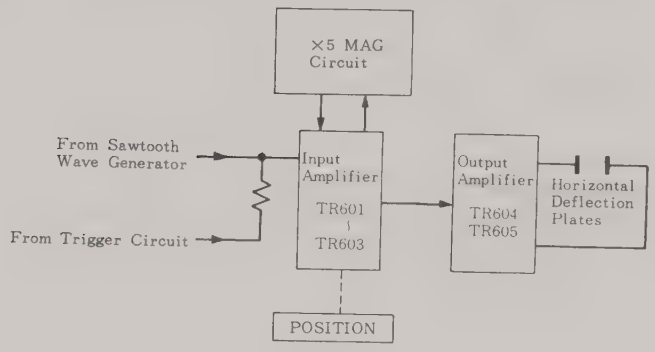


Fig. 4-14 Block Diagram of Horizontal Amplifier

Output Amplifier

The output amplifier, TR604 and TR605 converts the input signal supplied to the base of TR604 into a balanced signal, and amplifies the signal to an amplitude sufficient to deflect the electron beam in the horizontal direction.

Z Axis Amplifier

The circuit configuration of the Z axis amplifier is shown in Fig. 4-15. To control intensity of the display, one of the following four signals is supplied to the Z axis amplifier in accordance with control settings.

(1) Intensity control signal - varied with the INTENSITY control.

(2) Unblanking signal to intensify trace.

(3) Blanking signal to erase transient in CHOP operation.

(4) External intensity modulation signal - supplied to Z AXIS IN.

These signals are fed to the emitter of common-base amplifier IR750. The input impedance of the amplifier is determined to be very low. The input signal is amplified and sent to the collector of TR750.

When the intensity is minimized, diodes D750 and D751 operate to protect TR750. When the INTENSITY control is turned fully counterclockwise, TR750 is shut off and its collector potential increases toward +53 V. Diode D751 is reverse-biased and clamps the base potential of TR751; simultaneously, D750 is forward-biased and clamps the collector potential of TR750.

These diodes D750 and D751 operate similarly when the unblanking signal stepped in positive (return trace period when sweep is stopped). When the display is swept (i. e. when the unblanking signal is negative), D751 is forward-biased to connect the collector of TR750 to the base of TR751, and D751 is biased in the reverse direction.

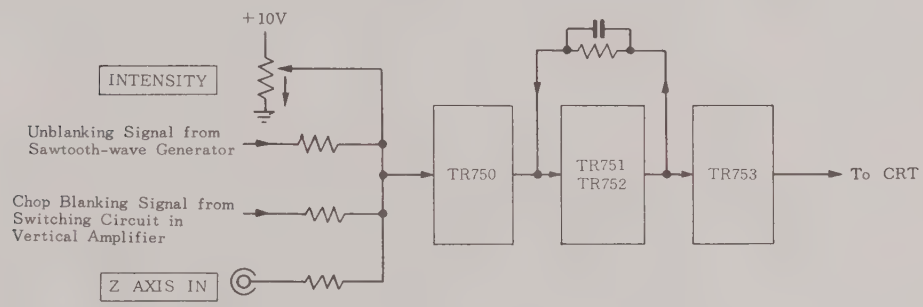


Fig. 4-15 Block Diagram of Z Axis Amplifier

During the CHOP operation, positive chop blanking pulses are supplied from R756 to shut off TR750. These pulses blank the display to erase transients in the CHOP operation.

The signal supplied to the base of emitter-follower TR751 is impedance lowered and supplied to the base of TR752 which amplifies and supplies the control signal to the base of TR753. The negative-feedback circuit (C752 and R760) between the collector of TR752 to the base of TR751 improves the frequency characteristics of this circuit. Capacitor C752 compensates the high-frequency component. The signal impedance is lowered through emitter-follower TR753 and supplied to the control grid of the CRT. Diode D752 conducts, when the collector potential of TR752 becomes negative, to accelerate the operation of TR753 toward negative.

CRT Circuit

The circuit configuration of the CRT circuit is shown in Fig. 4-16. This circuit produces the high voltage required to emit and accelerate

the electron beam in the CRT. The high voltages are produced by converting the low voltage into a sine-wave voltage (approx. 30 kHz) by the high-voltage oscillator. The converted high voltage is rectified to produce high DC voltages.

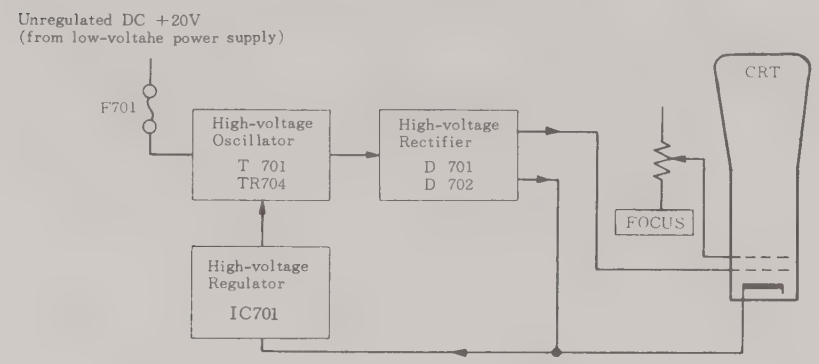


Fig. 4-16 Block Diagram of CRT Circuit

The high-voltage oscillator is composed of TR704, T701 and C702. When the POWER switch is turned on, current flows through the collector winding of T701. This current induces an electromotive force in the winding connected to the base of TR704 and causes the base potential of TR704 to rise in a positive direction. This increases the collector current and causes capacitor C702 to charge negative. The collector current increases until it saturates and the electromotive force stops. The charge on C702 decreases the base potential of TR704 and its collector current. The direction of the electromotive force is reversed, and C702 is charged positive until it reaches a point where TR704 conducts. The operation is repeated and the circuit oscillates at 30 kHz. Fuse F701 is connected to the high-voltage oscillator to prevent overloading the oscillator.

The stepped-up voltage across terminals #5 and #7 of T701 is half-wave rectified in the circuit D701-C703 - #5-#7, and is supplied to the control grid of the CRT. The other stepped-up voltage across terminals #8 and #9 is also half-wave rectified in the circuit D702-C707-C706-#8-#9, and supplied to the cathode of the CRT. Control R720 (INT ADJ) varies the DC potential of the terminal #8 to change the DC voltage across the control grid and cathode of the CRT and ultimately controls the intensity of the CRT.

The high-voltage regulator circuit feeds back a portion of the secondary voltage to the high-voltage oscillator in order to control

the oscillation intensity of the oscillator and to regulate the secondary output voltage at a constant value.

Assume that the cathode potential is reduced due to a variation in load. This variation is detected by the error amplifier constructed in IC701. Consequently, the collector current of TR704 increases and the cathode potential is maintained constant. HV ADJ R701 controls the oscillation amplitude.

Power Supply

Configuration of the power supply circuit is shown in Fig. 4-17. The power supply is composed of two regulated power supplies, a semi-regulated supply and an unregulated supply.

Power Supply Input

The AC power source voltage is supplied to power transformer T801 through fuse F801, power switch S801, and LINE VOLTAGE RANGE switch S802. When this instrument is operated on an AC 100 V line, the two primary windings of T801 are connected in parallel. In the 100 V position of the LINE VOLTAGE RANGE switch, windings #10-#11 and #13-#14 are connected in parallel, and in the 115 V position of the switch, windings #10-#12 and #13-#15 are connected in parallel. When the instrument operates on an AC 200 V line, the two primary windings are connected in series.

-10 V Power Supply

The -10 V power supply is also used as the voltage reference for the other power supplies. The voltage from the secondary (between terminals #5 and #6) of transformer T801 is rectified by bridge rectifiers a through d and filtered by capacitor C811. The output of the filter is fed to the series regulator TR808

Part of the series regulator output is fed back to the error amplifier which is constructed in IC801, to control the series regulator. Thus, the series regulator provides a stably-regulated low-ripple power to the load. Zener diode D806 provides the reference voltage for the comparator which is part of the error amplifier. Variable resistor R822 is used to calibrate the -10 V power supply.

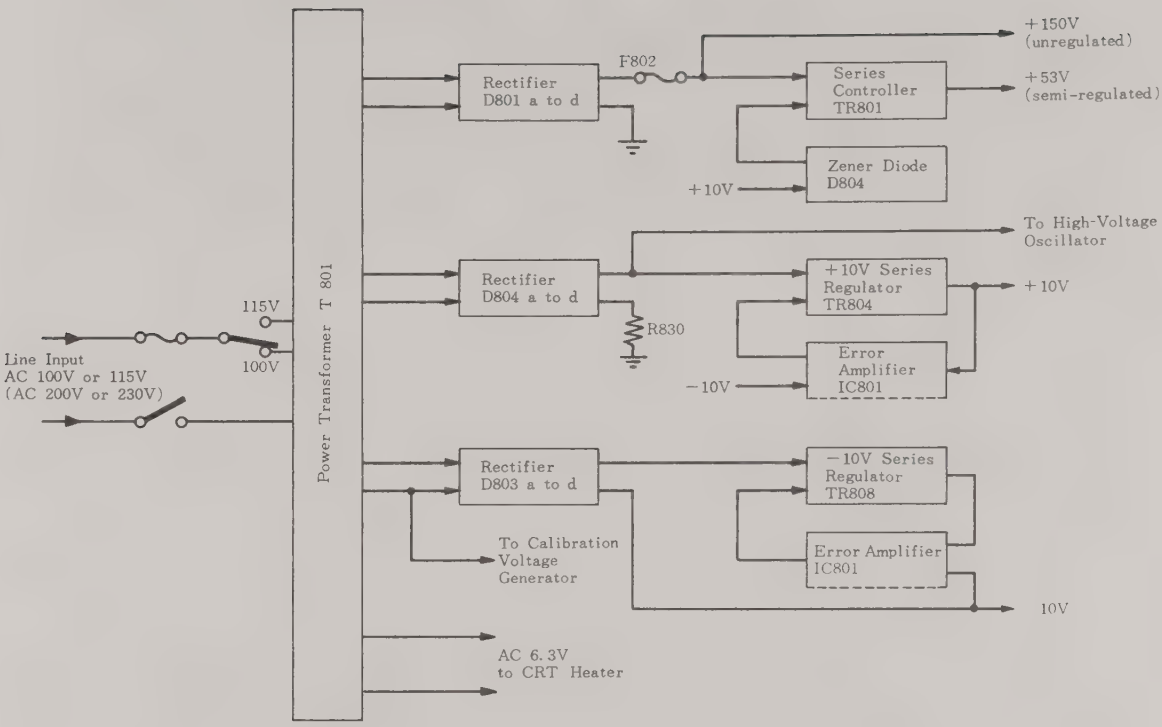


Fig. 4-17 Block Diagram of
Low-Voltage Power Supply

+10 V Power Supply

The DC voltage rectified by bridge rectifiers D802 a through d is filtered by capacitors C809 a and b, and supplied to +10 V series regulator TR804 and the CRT high voltage generator. The regulated -10 V is used for the reference voltage of the +10 V supply.

The output voltage of series regulator TR804 is regulated at a stable voltage being controlled by the error amplifier constructed in IC801. Variable resistor R813 is used to calibrate the +10 V supply voltage.

+53 V Power Supply and +150 V Power Supply

The non-regulated +150 V power supply is provided by bridge rectifiers D801 a through d and filter capacitor C801. The semi-regulated low-impedance +53 V power supply is provided from the emitter of series control TR801 whose base potential is maintained constant by zener diode D804 connected in series with the regulated +10 V power supply. Fuse 802 protects these power supplies against overcurrent.

CRT Heater Power Supply

An AC 6.3 V is supplied to the heater of CRT.

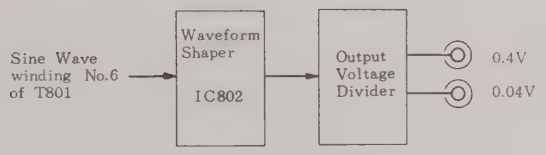


Fig. 4-18 Block Diagram of Calibrator

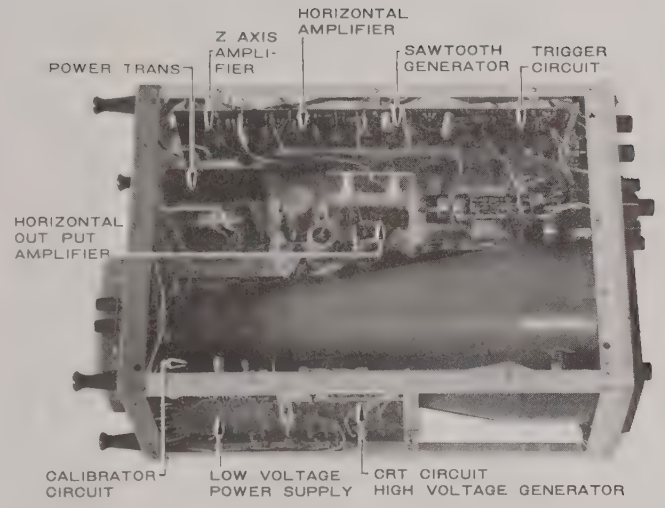
Calibrator

The circuit configuration of the calibrator is shown in Fig. 4-18. In this circuit, a line-frequency sine wave is shaped to form the square-wave output. This square-wave output is voltage-divided by resistors R855 and R856, and the voltages 0.4 V and 0.04 V (negative square wave) are supplied to the CAL OUT terminal. The amplitude of the CAL voltage is calibrated by control R854.

In this chapter, maintenance procedures which will ensure optimum operation of this instrument for a long period will be described.

In addition to proper maintenance, a thorough understanding of instrument performance and proper operation are essential to ensure optimum performance. (Chapter 2 "Pre-start Operation" is important.)

Preventive Maintenance 5-2
Troubleshooting 5-3
Parts Replacement 5-10


HORIZONTAL
AMPLIFIER
Z AXIS
AMPLI-
FIER
POWER TRANS
SAWTOOTH
GENERATOR
TRIGGER
CIRCUIT
HORIZONTAL
OUT PUT
AMPLIFIER
CALIBRATOR
CIRCUIT
LOW VOLTAGE
POWER SUPPLY
CRT CIRCUIT
HIGH VOLTAGE GENERATOR

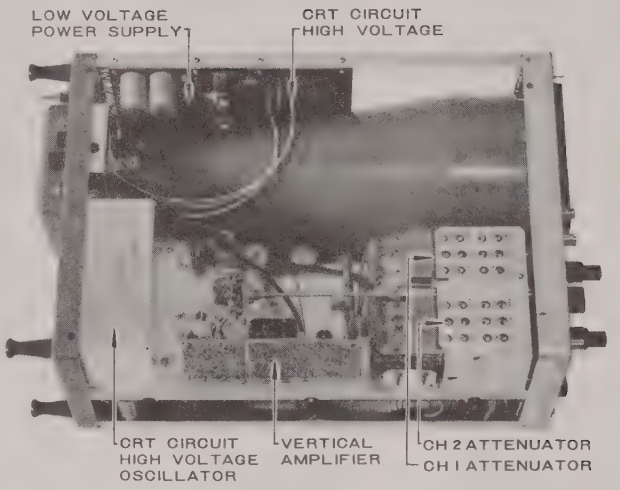

LOW VOLTAGE
POWER SUPPLY
CRT CIRCUIT
HIGH VOLTAGE
CRT CIRCUIT
HIGH VOLTAGE
OSCILLATOR
VERTICAL
AMPLIFIER
CH 2 ATTENUATOR
CH I ATTENUATOR

Fig. 5-1

PREVENTIVE MAINTENANCE

Maintenance procedures listed herein outline periodic tests which insure optimum operating efficiency and indicate preventive maintenance measures when required.

Cleaning

The instrument should be kept clean at all times. Dust accumulating in the instrument affects the radiation of heat and may cause overheating and the subsequent failure of parts. Foreign substances on contacts or connectors result in poor contact, and on printed circuit boards may cause arcing in damp climates or seasons. Suitable cleaning agents are listed in Table 5-1. Those agents indicated as unsuitable must not be used.

Table 5-1

Suitable Cleaning Agents	Alcohol and xylene
Unsuitable	Acetone, methyl-ethylketone, ether, lacquer thinner, and chemicals containing ketone series solvents

Front Panel Cover

Ordinary dirt on the front panel cover can be removed by washing the cover with a mild detergent. When grease or oil is present, use a soft cloth and one of the preferred cleaning agents listed in Table 5-1.

Front Panel and Knobs

Clean the front panel and the knobs with a damp cloth and a detergent or a suitable solvent. Use of alcohol may result in slight discoloring of the panel. If a powdered cleanser is used, wipe off the cleanser which remains after drying.

Dirt in Instrument

The best way to remove dirt or dust inside the instrument is to blow it out with air under pressure. Use of a soft brush in conjunction with the air will aid in the cleaning.

Dirt on CRT Surface

If the CRT graticule is left off for a long time, the face of the CRT may become dirty. Dust or fingerprints can be removed by wiping the surface with a soft cloth. Stains or sticking dirt can be removed with alcohol or detergent.

Graticule

Remove dust with a soft brush or smooth soft cloth such as a nylon stocking. Grease or sticking dirt should be removed with a mild detergent and warm water. After cleaning, rinse the filter in water and dry it thoroughly.

When the Instrument is to be Left Idle

When the instrument is not going to be used for a certain period, disconnect the probe and adaptor from the panel and cover the instrument with the protective dust cover. Store the accessories in the accessory kit and place the instrument in a dry place.

Visual Inspection

A simple visual check of the inside of the instrument will sometimes reveal various defects, such as charred resistors, defective contacts, or broken circuit boards. Immediate repair of these minor defects will prevent more serious troubles.

TROUBLESHOOTING

A thorough understanding of the overall system and circuit operation of this instrument will prove to be a valuable aid in troubleshooting. For this purpose, refer to Chapter 4 "Circuit Description".

Troubleshooting References

Circuit Diagrams

Circuits enclosed by dotted lines in the block diagram are on printed circuit boards.

The location of contacts and wafers of each rotary switch are also indicated. Contact positions on the side of a wafer closest to the front panel are denoted as A-F, and those on the rear side of the front wafer are A-R. Subsequent wafers are indicated as B-F and B-R. Concentric shaft switches are described as aA-F, aA-R, ... (switch

closest to front panel and driven by the outer shaft) and bA-F, bA-R, ... (rear switch, driven by the inner shaft).

Location of Circuit Boards

The circuit arrangement diagrams in Fig. 5-1 show the location of circuit boards, and will help in checking these circuits.

Wiring Color Code

Wires are color-coded according to their function. Two-colored wires are for the power supply circuits, and single-color wires are used for the general circuit wiring as shown in Tables 5-2 and 5-3. The standard color code of wires is shown in Table 5-3. Some wires in this instrument may deviate from the code. Shielded wires are not included in these codes.

Table 5-2 Color Code of Power Supply Wires (Two-Colored)

Low Voltage Source	Base Color	Stripe Color
-15 V	White	Black
+15 V	White	Red
+53 V	White	Blue
+150 V	White	Brown

Table 5-3 Color Code of General Wiring (Single-Color)

Circuit	Color
Collector or drain wires	Red
Base or gate wires	Yellow
Emitter or source wires	Blue
Positive voltage wires	Brown
Negative voltage wires	Purple or gray
Others (signal line, etc.)	White
Ground wires	Black

Resistor and Capacitor Color Code

The resistors and capacitors used in the circuit are color coded as shown in Fig. 5-2.

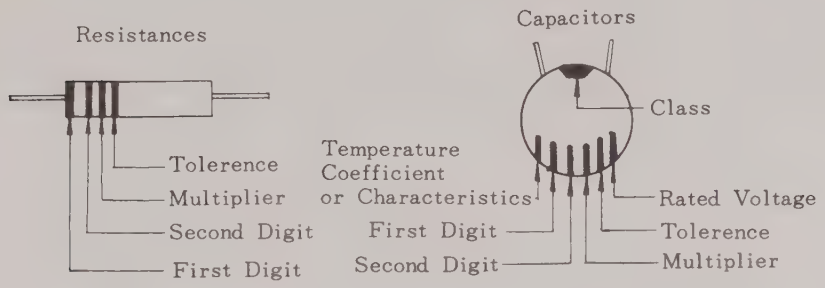


Fig. 5-2 Resistor and Capacitor Color Code

Color	Resistance or capacitance value		Tolerance for resistance (%)	Tolerance for capacitance (%)		Rated voltage (Capacitor)
	1st and 2nd significant digits	Multiplier		10 pF or more	10 pF or less	
Black	0	1	-	±20.0	±2.0	-
Brown	1	10	±1	± 1.0	-	-
Red	2	10^2	±2	± 2.0	-	250 V
Orange	3	10^3	-	± 2.5	-	300 V
Yellow	4	10^4	-	-	-	-
Green	5	10^5	-	± 5.0	±0.5	500 V
Blue	6	10^6	-	+100 (- 0)	-	-
Purple	7	10^7	-	-	-	-
Gray	8	10^8	-	±10.0	±0.25	-
White	9	10^9	-	-	±1.0	1000 V
Gold	-	10^{-1}	±5	-	-	-
Silver	-	10^{-2}	±10	-	-	-
Not colored	-	-	±20	-	-	-

Identification of Diode and Transistor Elements

Element identifying marks for the various diodes and transistors are shown in Tables 5-4 and 5-5.

Table 5-4 Type and Element Identification of Diodes

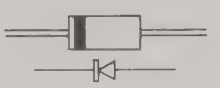
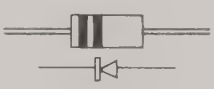
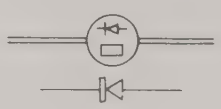
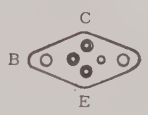
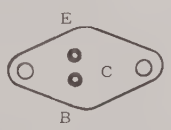
Type	Element Identification
Tunnel Diode 1 S 1 7 6 1	
1 S 9 5 3 H W 43 A R D 6 A	
1 S 1 5 4 4	
H F S D - 1	

Table 5-5 Type and Element Identification of Transistors

Type	Element Identification
XA495 C/D	
2 S C 321 (H) B 2 S D 221 2 S C 154 C	
M K — 10 — 2	
2 S D 222 2 S D 224	
2 S C 6 8 5	

Measuring Instruments Required for Troubleshooting

The following instruments are required for troubleshooting.

(1) Multimeter

Input Impedance: 10 megohms

Voltage Range : Normal range 0～300 V
(Measurable to 2 kV)

Ohm Range : 0～20 megohms

(2) Transistor Curve Tracer

IWATSU Transistor Curve Tracer TT-502 or TT-505

(3) Synchroscope

Frequency Bandwidth: DC ~ 5 MHz

Sensitivity : 10 mV/cm

Prior to Troubleshooting

First, it should be determined whether the instrument is actually defective, or other external conditions are responsible for the trouble indications. For example, when the power source voltage exceeds the allowable operating range, or external noise is induced in the test set-up, the display will become irregular.

When the display at a certain sweep rate is somewhat irregular and it is difficult to determine whether the instrument is defective, it is advisable to observe another type of signal and see if the same irregularity occurs.

Troubleshooting Procedure and Sequence

The following procedures and sequence of troubleshooting will help to save time.

(1) Before removing the covers from the instrument, verify all control functions described in Chapter 2, "Operating Procedures." This should aid in isolating the defective portion to a particular circuit such as the low voltage power supply, CH 1 preamplifier, CH 2 preamplifier, trigger generator and so on. (Refer to the following section "Isolation of Defective Circuits According to Trouble Symptoms.")

(2) Next, remove the cover on the side of the instrument which contains the suspicious circuit, and visually check components, wires, and the circuit pattern for irregularities such as charred wires or resistors, defective contacts or broken wires. Various causes of trouble may be detected by a thorough visual inspection.

(3) Check the low and high voltage supplies. (Refer to Chapter 6 "Low and High Voltage Supplies.") Trouble in the low voltage power supply has considerable influence on other circuits. Abnormal voltage from power supplies must be corrected.

(4) Next, use a multimeter or test synchroscope to check the operation of individual circuits, referring to the circuit diagrams in the last section, and localize the defective circuit.

(5) Check the characteristics of suspicious active elements (transistors or diodes) and passive parts (resistors or capacitors, etc.), and replace any defective part(s) with new one.

Troubleshooting with Particular Symptoms

Since it is impossible to forecast all possible troubles in this synchroscope, only typical troubles and troubleshooting hints will be described. Follow the procedures described in items (3) to (5) above to isolate defective parts.

No Spot (electron beam)

Any of the CRT circuit, Z-axis amplifier, vertical deflection system circuit and horizontal amplifier are responsible for this trouble. Although it is a rare case, two of these circuits may cause trouble at the same time.

Change the MODE switch from CH 1 to CH 2, or vise versa, to confirm that the spot is present on both channels. If the spot is not present on either channel, the preamplifier in that channel is probably defective. If the spot is not present in both channels, check that the DC voltage on each deflection plate, or the output voltages of the vertical and horizontal amplifiers, are balanced at a certain position of the POSITION control for the deflection system. When the deflection plate voltages for one channel are balanced but the spot is not present, the CRT circuit or Z-axis amplifier is probably defective. The responsible circuit for the trouble can be determined by checking the Z-axis amplifier voltages and unblanking signal waveform.

Spot is Present, but Sweep does not Operate

Set the TIME/CM (& EXT HORIZ) switch in the EXT HORIZ position and turn the POSITION control (horizontal). When the spot moves horizontally the full width of the display with the rotation of this control, and a normal horizontal display is obtained in accordance with the operation described in Chapter 2 "XY Scope Operation," the horizontal amplifier is normal, and the sawtooth generator circuit is responsible for the defect.

Sweep Present, but not Triggered

When the display cannot be triggered by neither the internal nor external trigger, the trigger generator is defective. If the display is triggered only by an external triggering signal (of rated amplitude), the trouble should be between the vertical deflection system and trigger circuit.

Dual Trace Inoperative

When only the ALTER mode is inoperative, the circuit between the alternate pulse output circuit and the alternate amplifier in the switching circuit may be the cause of the trouble. In very rare cases, the switching circuit may be defective. When both the ALTER and CHOP modes are inoperative, the switching circuit is probably defective.

Horizontal Sweep is not Linear

If the sweep time in the right and left side of the display area is not equal, and the display linearity varies with rotation of the POSITION control, the horizontal amplifier is probably defective, and if the linearity does not vary with the POSITION control, the sweep generator is the most likely cause.

PARTS REPLACEMENT

The procedure for removing panel covers and parts in order to perform visual checking of circuits or defective components will be described.

Removal of Panel Covers

The top cover can be removed by removing 12 screws located on the top and side panels. The bottom cover can be removed by removing the eight screws located on the side and bottom panels.

Replacement of Semiconductor Elements

Suitable transistors or diodes must be used for replacement. Specially selected transistors and diodes are employed in major circuits of this instrument in order to ensure the characteristics described in Chapter 1. These selected transistors and diodes are shown in Table 5-6.

The semiconductors are sensitive to heat. When the transistor leads are soldered, use heat sinks to prevent the conduction of heat to the actual internal elements. Replace parts as quickly as possible as heat may cause the printed circuits to separate from the laminate.

Table 5-6 Specially Selected Transistors and Diodes

Circuit	Circuit No. of Transistors
VERTICAL AMPLIFIER	TR 101 • TR 102 (Twin) TR 105 • TR 106 (Twin) TR 109
VERTICAL AMPLIFIER	D 101, D 102, D 111, D 112

Replacement of Resistors and Capacitors

Specially selected passive elements, (resistors and capacitors), are used for the instrument, therefore defective parts should be replaced with suitable replacements.

Burnt resistors or shorted capacitors may result from short-circuiting or serious deterioration of transistors or diodes. Check the cause of the trouble, and replace any defective active elements as well as passive elements.

Fuse Replacement

The power line fuse is located on the rear panel, and power supply fuses for low voltage circuit are collectively mounted on the left side of the instrument. Details of fuses are shown in Table 5-7.

Table 5-7 Fuses

Circuit Symbol	Fuse Type	Function	Location of Fuse Holder
F 701	1 A quick acting	CRT circuit	High voltage section at the bottom of the instrument
F 801	1 A quick acting	For line voltage	Rear panel
F 802	0.5 A quick acting	+150 V & +53 V	Left rear section

Removal of Circuit Boards

The printed circuit boards can be removed by disconnecting the wires to the board and removing the mounting screws.

The external connections to the board must be properly soldered to the board after replacement in order to avoid damage to transistors and/or resistors.

CRT Replacement

Handle the CRT with extreme care as excessive force or shock may cause it to break or crack. For removing the CRT from the instrument, pull out the CRT as it is contained in the shielding case. Then, extract the CRT out of the shielding case.

Remove the CRT in the following sequence.

(1) Remove both top and bottom panels.

(2) Remove the rectangular protruding cover for CRT from the rear panel by extracting four screws.

(3) Remove the CRT socket slowly.

(4) Remove three screws which secure the rear section of the shielding case to the case.

(5) Remove two screws which secure the shielding case for the CRT from the side of front panel.

(6) The shielding case can be removed with the CRT in it.

(7) Pull out the CRT from the top (or bottom) moving it backward.

(8) The CRT can be completely removed out of the shielding case.

Reinstall the CRT in the reverse sequence.

Removal of Graticule

When the bezel has been removed, the graticule is readily removable.

Removal of Bezel

Directly pull to this side from the front panel.

Like all measuring instruments, this synchroscope must be calibrated after a certain periods of use. The extent of the calibration, whether overall or partial, differs with the operating condition of the instrument. However, the functions which require calibration can be easily determined by checking the accuracy of the vertical deflection sensitivity, attenuator (VOLTS/CM) phase, sweep time and other functions with the internal CALIBRATOR or the accurate external instruments.

In some cases, recalibration may be required when parts are replaced. It should be noted that partial calibration may influence other circuits. For example, the power supply influences the operation of almost all circuits, and the high voltage power supply varies the vertical and horizontal deflection sensitivity.

Low-Voltage Power Supply 6-1
High-Voltage Power Supply 6-1
Intensity 6-2
Vertical Deflection Sensitivity 6-2
VOLTS/CM (Attenuator) Phase 6-2
LEVEL CENTER 6-4
TRIG THRESHOLD 6-7
Sweep Time 6-7
SWP LENGTH 6-7
X5 MAG CENTER 6-7
EXT HORIZ DC BALANCE 6-7
EXT HORIZ GAIN 6-7
CAL OUT 6-8

Low-Voltage Power Supply

The low-voltage power supplies must be checked prior to calibration of other circuits. The low-voltage power is supplied to all circuits, therefore, the specifically regulated power source voltage must be adjusted by using an accurate DC voltmeter (accuracy, class 0.5 or above).

Both regulated and unregulated power supplies are provided as shown in Table 6-1. The location of test points on the power supplies is shown in Fig. 6-1. Measure the voltage between the test point and the chassis and if any error is found, adjust the output voltage in the sequence shown in Table 6-1. Variable resistors for each adjustment are also indicated in Table 6-6.

Table 6-1

Power Supply	Type	Color Code of Wiring	Tolerance	Ripple Voltage	Measuring Condition	Sequence Adjustment	Variable Resistor for Adjustment
-10 V	Regulated	White/Black	±0.2 V	5 mV or less	Calibrate at line voltage of 100 V	1	R822
+10 V	"	White/Red	±0.2 V	5 mV or less	"	2	R813
+53 V	Semi-regulated	White/Blue		15 mV or less	"	Confirm	-
+150V	Unregulated	White/Yellow			"	Confirm	-

High Voltage Power Supply

Variation of the high voltage will cause variation in the deflection sensitivity of both the vertical and horizontal axes of the CRT. An excessive voltage variation will vary the focus and the intensity of CRT. The voltage in Table 6-2 should be adjusted or confirmed.

Table 6-2

High Voltage Power Supply	Color Code of Wiring	Normal Values
CRT Cathode Voltage	White/Green	-1450 V ±50 V

First calibrate the cathode with H. V ADJ adjustment, R701 (refer to Fig. 6-6) to cause the voltage between the test point (refer to Fig. 6-1) and the chassis to become -1450 V.

Intensity

The optimum intensity is obtained by adjusting INT ADJ R720 (see Fig. 6-6) so that the trace will disappear when INTENSITY control is turned fully counterclockwise and the trace will appear when the control is turned clockwise.

Vertical Deflection Sensitivity

Connect a calibrated signal generator (CR OSCILLATOR) to the INPUT connector, and feed 1 kHz signal exactly 20 mVp-p in amplitude. Set the VARIABLE switch to the CAL position and the VOLTS/CM to 10 mV range. The amplitude should be 2 cm. Position the display in the center of the graticule. Adjust the GAIN ADJ R 114 and R134 for the correct display amplitude (See Fig. 6-2). R114 is for CH1 and R134 is for CH2.

Change the VOLTS/CM switch to each position and confirm that the display amplitude on the CRT is 2 cm when the twice voltage of the indicated value is applied. The sensitivity of the vertical amplifier in all positions should be automatically within ± 3 % of the indicated value. If an error exceeds the rating, the attenuator element for that range is responsible for the error.

VOLTS/CM (Attenuator) Phase

If the phase characteristics of the attenuator are not equal for each range, frequency response will deteriorate and distortion will occur in the displayed waveform. Connect the square wave generator (rise time .1 μsec or less) output to the INPUT connector of the instrument.

Set the VOLTS/CM switch to 10 mV range. Control the square wave generator output so that the display amplitude will be $3 \sim 4$ cm on the graticule center. During this control operation, turn the VARIABLE switch fully clockwise.

Now, trigger the sweep and start calibration from the portion (A) indicated in Fig. 6-3.

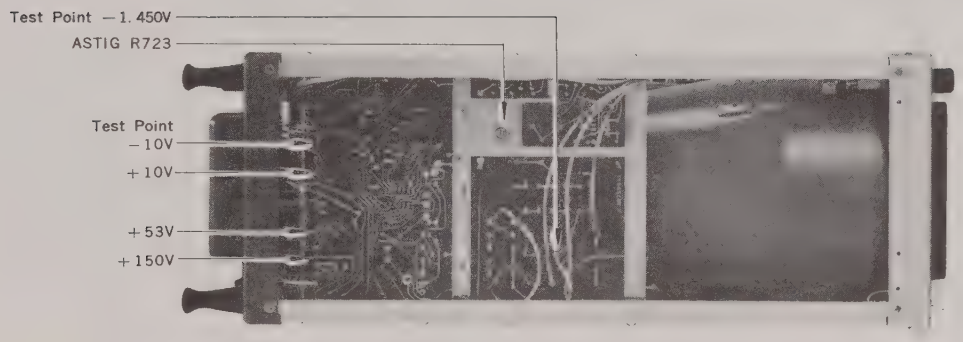


Fig. 6-1 Left Side View

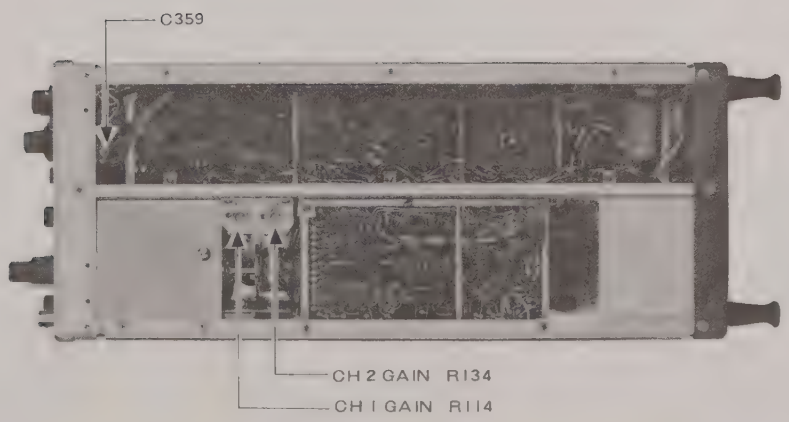


Fig. 6-2 Right Side View

For calibration of CH 1, adjust C 230 and for CH 2, C 280. Change the VOLTS/CM switch to 20 mV range and adjust for the vertical amplitude of 3 4 cm on the graticule. Control C 205 for CH 1 and C 255 for CH 2 in the similar manner. Calibrate for each range in the sequence indicated in Table 6-3.

Next, calibrate the portion Ⓑ. Connect the probe to the INPUT connector and connect the other end of the probe to the square wave generator.

Change the VOLTS/CM switch to 20 mV range, and adjust the square wave generator output for the vertical amplitude of 3 4 cm on the graticule. First calibrate the probe phase, referring to Fig. 3-6. Second, set the VOLTS/CM to 10 mV range and adjust the square wave generator output so that the vertical amplitude of the display on the graticule will become 3 ~ 4 cm. Calibrate C 201 for CH 1 and C 251 for CH 2. (Refer to Fig. 6-5.) Then calibrate portion Ⓑ in the procedures shown in Table 6-3.

LEVEL CENT

Change the TIME/CM (& EXT HORIZ) within the TIME/CM range, SOURCE switch to INT NORM, and COUPLING to AC positions. Feed a 1 kHz sine wave to the INPUT connector, set the LEVEL (& AUTO) control to mid-position and trigger the display properly. Then calibrate with LEVEL CENT R 323 (Fig. 6-6) so that the display is triggered symmetrically on the displayed waveform at both + and - slope mode of the SLOPE switch.

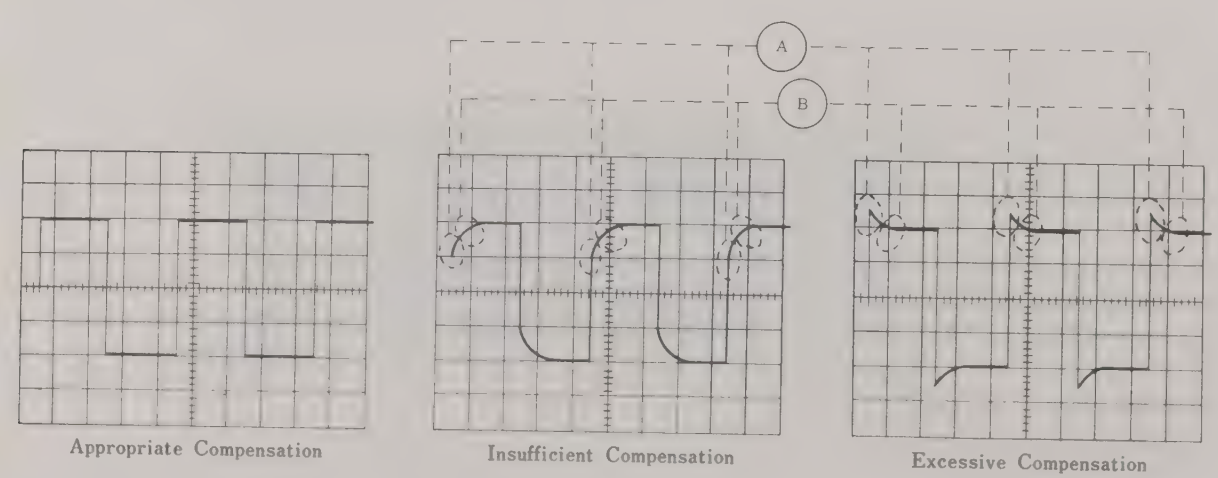


Fig. 6-3 Calibration of VOLTS/CM Phase

Table 6-3

VOLTS/CM Range	Calibration Trimmer					
	(A)			(B)		
	Sequence Adjustment	CH 1	CH 2	Sequence Adjustment	CH 1	CH 2
10 mV	1	C230	C280	12	C201	C251
20 mV	2	C205	C255	11	Probe	Probe
50 mV	3	C207	C257	13	Automatically calibrated	Automatically calibrated
.1	4	C210	C260	14	C209	C259
.2	5	C204	C254	15	Automatically calibrated	Automatically calibrated
.5	6	C206	C256	16	Automatically calibrated	Automatically calibrated
1	7	C213	C263	17	C212	C262
2	8	C203	C253	18	Automatically calibrated	Automatically calibrated
5	9	C202	C254	19	Automatically calibrated	Automatically calibrated
10	10	C216	C266	20	C215	C265

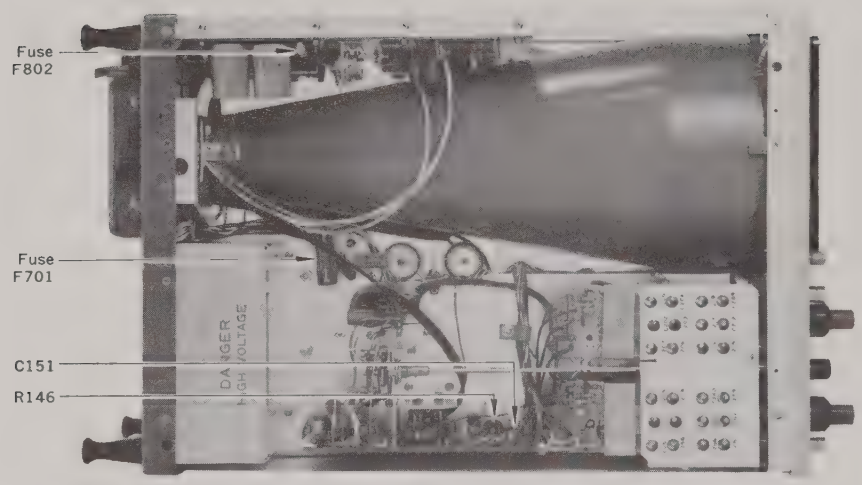


Fig. 6-4 Lower Section

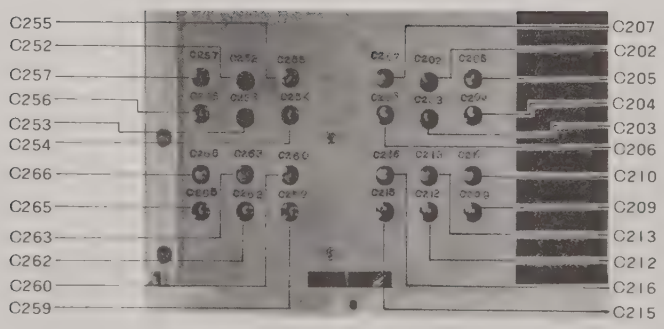


Fig. 6-5 Calibration of VOLTS/CM Phase

TRIG THRESHOLD

Triggering may not be effected or sweep may free run unless correctly calibrated setting the LEVEL (& AUTO) control to the LEVEL position. Correctly calibrate with TRIG THRESHOLD R 403 (See Fig. 6-6) for correct triggering.

Sweep Time

Set the TIME/CM (& EXT HORIZ) switch to 1 msec range and the VARIABLE switch to the CALIB position. Feed signals having accurate time interval of 1 msec, and calibrate with SWP CAL R 610 (See Fig. 6-6) so that the signal will coincide with the scale.

SWP LENGTH

Adjust the trace length of the horizontal sweep, so that it will be 10.5 to 12 cm. Calibration can be made with SWP LENGTH R 428 (See Fig. 6-6).

X5 MAG CENTER

This adjustment is to ensure that the magnified display will start from the center of the graticule. Set the starting point of the magnified display to the vertical center line of the graticule by adjusting the POSITION control, and push the POSITION switch (the sweep is not magnified at this time). Calibrate the sweep starting point to the center of the scale with x5 MAG CENT R 601 (See Fig. 6-6).

EXT HORIZ DC BAL

Calibrate with the EXT HORIZ DC BAL R 305 (See 6-6) so that the horizontal position of the spot will not vary when the VARIABLE {TIME/CM (& EXT HORIZ)} is rotated for external triggering.

EXT HORIZ GAIN

This control is used for deflection sensitivity adjustment for external sweep. For operating this control, set the TIME/CM (& EXT HORIZ) to EXT HORIZ position, VARIABLE to CALIB, SOURCE TO EXT, and the COUPLING to EXT DC or (AC) positions.

Next, connect the CAL OUT 0.4 to the TRIG OR HORIZ IN and adjust the EXT HORIZ GAIN R 633 (See Fig. 6-6) so that the amplitude of the display will become 2 cm on the graticule.

CAL OUT

This control is used for output adjustment of the calibration voltage. Adjust the CAL ADJ R854 (See Fig. 6-6) after calibrating the vertical deflection sensitivity.

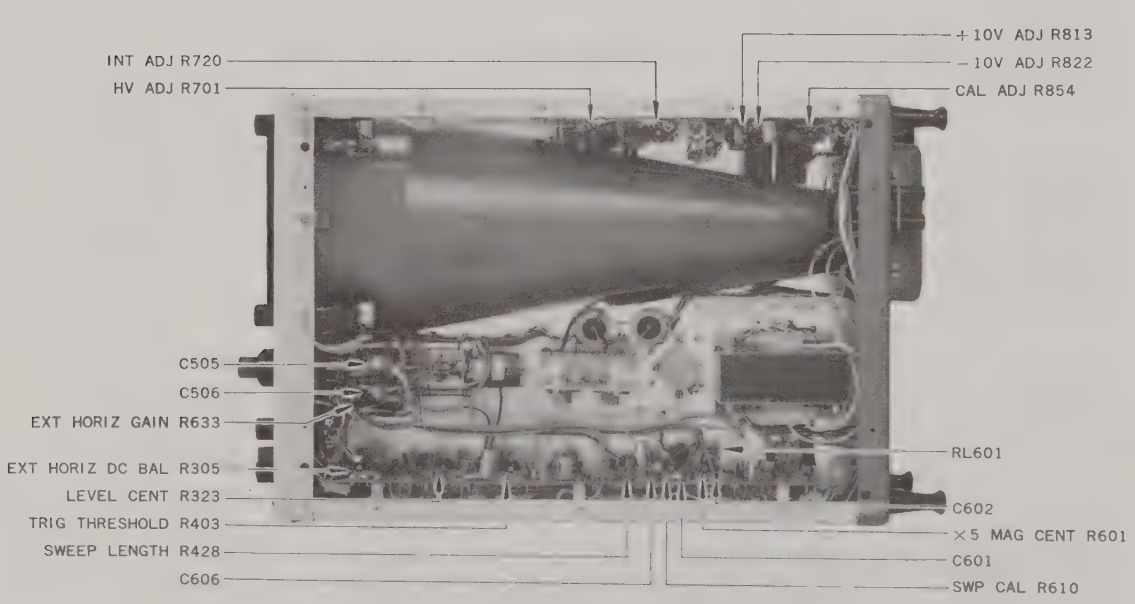


Fig. 6-6 Upper Section

Abbreviations used in this manual are as follows:

For units:

A	ampere
mA	milliampere
μA	microampere
nA	nanoampere (10^{-9} A)
dB	decibel
div (DIV)	division
g	gram
kg	kilogram
Hz	hertz
kHz	kilohertz
MHz	megahertz
GHz	gigahertz
m	meter
cm	centimeter
mm	millimeter
sec (SEC)	second
msec	millisecond
μsec	microsecond
nsec	nanosecond (10^{-9} sec)
psec	picosecond (10^{-12} sec)
F	farad
μF	microfarad
pF	picofarad
V	volt
mV	millivolt
μV	microvolt
VA	voltampere
W	watt
mW	milliwatt
Ω	ohm
MΩ	megohm
kΩ	kilohm
rms	root mean square
p-p	peak to peak

Others

AC	alternate current
ADJ	adjust
ALTER	alternate
ASTIG	astigmatism
AUTO (Auto)	automatic

BAL	balance
CAL	calibrated
CAL OUT	calibrator output
CENT	center
CH 1	channel 1
CH 2	channel 2
CHOP	chopped
DC	direct current
EXT	external
GND	ground (earth)
HF REJ	high frequency reject
HORIZ	horizontal
ILLUM	illumination
INT	internal
INTEN	intensity
LF REJ	low frequency reject
MAG	magnifier
NORM	normal
SENS	sensitivity
SWP	sweep
TRIG	trigger
UNCAL	uncalibrated
VERT	vertical

PARTS LIST

ORDERING INFORMATION

Replacement parts may be ordered through an IWATSU Representative or directly from the factory. To be certain of receiving the proper parts, always include the following information with the order:

a. Model Number and serial number of the instrument on which the parts will be installed.

b. Circuit reference number and subassembly name, if applicable, for which the part is intended. If the part does not have a circuit reference, the description from the parts list should be used.

c. Iwatsu part number.

For factory repair, contact the IWATSU agent and include the following information:

a. Model number and serial number of the instrument on which the work is to be performed.

b. Details concerning the nature of the malfunction, or, type of repair desired.

Shipping instructions will be sent to you promptly.

HOW TO USE THIS PARTS LIST

The parts list is divided into subsections corresponding to the schematic diagrams such as VERTICAL AMP, TRIG CIRCUIT, SWEEP GENERATOR, HORIZONTAL AMP, CRT CIRCUIT and POWER SUPPLY. Component locations can be determined from the schematic diagrams, each component appears only once in the parts list. At the beginning of each subsection are listed part numbers for any complete subassemblies in that category that are available as replacement parts. These subassemblies may include individually-listed components; care should be taken to locate malfunctions to the lowest possible level of replacement part and thus avoid the time and cost involved in "over-repair".

ABBREVIATIONS

Cap. ..... Capacitor
- cer. ..... ceramic
- elect. ..... aluminium electrolytic chemical condenser
- elect. tan. .... tan-talum electrolytic chemical condenser
- poly. ..... polyethytel film condenser

Res. ..... Resistor
- w.w. ..... wire wound
- comp. ..... composition

FET ..... Field Effect Transistor

Diode
- T. Diode ..... Tunnel Diode
- Z. Diode ..... Zenner Diode

Var. ..... variable

VERTICAL AMPLIFIER

CIRCUIT REFERENCE	DESCRIPTION	IWATSU PART No.
C101	Cap., 0.1μF, 600WV, ±20%, poly.	74130-2820
C102	Cap., 0.01μF, 500WV, +80 -20%, cer.	74060-0730
C103	Cap., 3.3μF, 3.15WV, ±20%, elect. Tan.	74120-3540
C104	Cap., 0.01μF, 50WV, +80 -20%, cer.	74060-0580
C105	Cap., 0.01μF, 25WV, +80 -20%, cer.	74060-0560
C106	Cap., 0.01μF, 50WV, +80 -20%, cer.	74060-0580
C107	Same as C106	
C108	Same as C106	
C109	Same as C106	
C110	Same as C105	
C111	Same as C101	
C112	Same as C102	
C113	Same as C103	
C114	Same as C104	
C115	Same as C105	
C116	Cap., 3.3μF, 16WV, ±20%, elect. Tan.	74120-0270
C117	Same as C116	
C118	Same as C105	
C150	Cap., 0.02μF, 25WV, +80 -20%, cer.	74060-0570
C151	Cap., 7pF, 250WV, var.	74110-0660
C152	Cap., 4pF, 50WV, ±0.5pF, cer.	74050-4720
C155	Cap., 47μF, 250WV, -10 +100%, elect.	74120-0280
C155b	Cap., 100μF, 16WV, -10 +150%, elect.	74120-3340
C155c	Same as C155b	
C171	Cap., 820pF, 50WV, ±20%, cer.	74060-3000
C172	Cap., 0.1μF, 25WV, +80 -20%, cer.	74060-2330
C173	Same as C105	
C174	Same as C105	
C175	Cap., 470pF, 500WV, +80 -20%, cer.	74060-2540
C176	Same as C104	
C177	Cap., 27pF, 50WV, ±10%, cer.	74050-5760
C178	Cap., 100pF, 50WV, ±10%, cer.	74050-1710
C179	Same as C178	
C180	Same as C178	
C181	Cap., 33μF, 16WV, -10 +100%, elect.	74120-3080
C190	Cap., 300pF, 50WV, ±5%, cer.	74050-1800
R101	Res., 47, 1/4W, ±20%, compo.	74253-0750
R103	Res., 1M, 1/2W, ±2%, carbon	74241-1130
R104	Same as R101	
R105	Res., 5.6, 1/4W, ±5%, compo.	74253-1960
R106	Res., 2.7k, 1/4W, ±5%, carbon	74223-1980
R107	Same as R106	
R108	Same as R101	
R109	Res., 910, 1/4W, ±5%, carbon	74223-3360
R110	Res., 20k, 1/4W, ±5%, carbon	74223-2170
R111	Res., 50k, var., (DC BAL), carbon	74323-0470
R112	Same as R106	
R113	Same as R106	
R114	Res., 100, var., (CH-1 GAIN), carbon	74322-0010
R115	Res., 300, var., (VARIABLE), carbon	74325-2130
R115b	Res., 470, 1/4W, ±5%, carbon	74223-2630
R116	Same as R110	
R117	Same as R110	
R118	Res., 100, 1/4W, ±20%, compo.	74253-0850
R119	Res., 50k, var., (POSITION), carbon	74323-0480
R121	Same as R101	
R123	Same as R103	
R124	Same as R101	
R125	Same as R105	
R126	Same as R106	
R127	Same as R106	
R128	Same as R101	
R129	Same as R109	
R130	Same as R110	
R131	Same as R111	
R132	Same as R106	
R133	Same as R106	
R134	Same as R114 (CH-2 GAIN)	
R135	Same as R115	
R135b	Same as R115b	
R136	Same as R110	
R137	Same as R110	
R138	Same as R118	
R139	Same as R119	
R140	Res., 10, 1/4W, ±20%, compo.	74253-0650
R141	Same as R101	
R142	Res., 3k, 1/4W, ±5%, carbon	74223-1990
R143	Same as R140	
R145	Res., 1.8k, 1/4W, ±5%, carbon	74223-1940
R146	Res., 5k, var., carbon	74349-0320
R147	Res., 1k, 1/4W, ±5%, carbon	74223-1900
R148	Res., 680, 1/4W, ±5%, carbon	74223-2550
R149	Same as R147	
R150	Same as R148	
R151	Res., 7.5k, 1/2W, ±2%, carbon	74241-0630
R152	Same as R151	
R153	Res., 820, 1/2W, ±2%, carbon	74241-0420
R154	Res., 270, 1/4W, ±5%, carbon	74223-2700
R155	Same as R154	
R156	Res., 47k, 1/4W, ±5%, carbon	74223-2240
R157	Same as R156	
R158	Res., 2k, 1/4W, ±5%, carbon	74223-1950
R159	Res., 10k, 1W, ±2%, carbon	74242-0520
R160	Same as R159	
R161	Res., 82, 1/4W, ±5%, carbon	74223-3370
R162	Res., 150, 1/4W, ±5%, carbon	74223-3280
R163	Same as R162	
R164	Same as R159	
R165	Same as R159	
R166	Res., 510, 2W, ±2%, carbon	74243-0290
R167	Same as R154	

CIRCUIT REFERENCE	DESCRIPTION	IWATSU PART No.
R168	Same as R154	
R169	Same as R154	
R170	Same as R154	
R171	Same as R158	
R172	Res., 43k, 1/4W, ±5%, carbon	74223-2230
R173	Res., 4.7k, 1/4W, ±5%, carbon	74223-2040
R174	Same as R118	
R175	Same as R147	
R176	Res., 24k, 1/4W, ±5%, carbon	74223-3400
R177	Res., 560, 1/4W, ±5%, compo.	74253-1640
R178	Same as R142	
R180	Res., 10k, 1/4W, ±5%, carbon	74223-2130
R181	Res., 1.5k, 1/4W, ±5%, carbon	74223-1930
R182	Res., 390, 1/4W, ±5%, carbon	74223-2500
R183	Same as R182	
R184	Same as R142	
R185	Same as R142	
R186	Res., 27k, 1/4W, ±2%, carbon	74244-0590
R187	Same as R186	
R188	Same as R142	
R189	Same as R142	
R191	Res., 2.4k, 1/4W, ±5%, carbon	74223-1970
R192	Same as R115b	
R193	Same as R115b	
R194	Same as R140	
R195	Same as R101	
R196	Same as R180	
R197	Res., 12k, 1/4W, ±5%, carbon	74223-2150
R198	Res., 3.3k, 1/4W, ±5%, carbon	74223-2000
R199	Same as R106	
D101	Diode, 1S1690N	74040-4100
D102	Same as D101	
D103	Diode, 1S953	74040-1720
D104	Same as D103	
D105	Same as D103	
D106	Same as D103	
D107a	Same as D103	
D107b	Same as D103	
D108a	Same as D103	
D108b	Same as D103	
D111	Same as D101	
D112	Same as D101	
D113	Same as D103	
D114	Same as D103	
D115	Same as D103	
D116	Same as D103	
D120	Same as D103	
D121	Same as D103	
D140	Same as D103	
D150	Same as D103	
D151	Same as D103	

CIRCUIT REFERENCE	DESCRIPTION	IWATSU PART No.
TR101	FET, MK-10-2-D	74030-3870
TR102	Same as TR101	
TR103	Transistor, 2SC321 Ⓗ B	74030-4500
TR104	Same as TR103	
TR105	Same as TR101	
TR106	Same as TR101	
TR107	Same as TR103	
TR108	Same as TR103	
TR109	Same as TR101	
TR110	Same as TR103	
TR111	Same as TR103	
TR112	Transistor, 2SC154C	74030-4000
TR113	Same as TR112	
TR114	Same as TR112	
TR115	Same as TR112	
TR116	Transistor, XA495C/D	74030-5220
TR117	Same as TR112	
TR118	Same as TR103	
TR119	Same as TR103	
TR120	Same as TR103	
S101	Slide switch	74430-1430
S102	Same as S101	
S103	Rotary switch (MODE)	74431-6110
S104	Rotary switch (VOLTS/CM)	74431-6106
S105	Same as S104	
J101	Connector, BNC-R, (INPUT)	74500-2350
J102	Same as J101	
TB101	Terminal	74510-0140
T101	Pulse transformer	74400-4680

ATTENUATOR

C201	Cap., 8pF, 350WV, var.	74110-0070
C202	Cap., 7pF, 250WV, var.	74110-0660
C203	Same as C202	
C204	Same as C201	
C205	Cap., 12pF, 350WV, var.	74110-0080
C206	Same as C205	
C207	Same as C205	
C208	Cap., 10pF, 500WV, ±1pF, cer.	74050-1920
C209	Cap., 20pF, 350WV, var.	74110-0100
C210	Same as C205	
C211	Cap., 20pF, 500WV, ±5%, cer.	74050-6370
C212	Same as C209	
C213	Same as C205	
C214	Cap., 470pF, 300WV, ±2%, mica	74090-4910
C215	Same as C209	

CIRCUIT REFERENCE	DESCRIPTION	IWATSU PART No.
C216	Same as C201	
C217	Cap., 2700pF, 300WV, ±2%, mica.	74090-4900
C230	Cap., 60pF, 350WV, var.	74110-1000
C231	Cap., 33pF, 500WV, ±10%, cer.	74050-2500
C251	Same as C201	
C252	Same as C202	
C253	Same as C202	
C254	Same as C201	
C255	Same as C205	
C255b	Cap., 3pF, 50WV, ±0.5pF, cer.	74050-5450
C256	Same as C205	
C257	Same as C205	
C258	Same as C208	
C259	Same as C209	
C260	Same as C205	
C261	Same as C211	
C262	Same as C209	
C263	Same as C205	
C264	Same as C214	
C265	Same as C209	
C266	Same as C201	
C267	Same as C217	
C280	Same as C230	
C281	Cap., 68pF, 500WV, ±10%, cer.	74050-4090
R201	Res., 10, 1/4W, ±20%, compo.	74253-0650
R202	Same as R201	
R203	Res., 500k, 1/2W, ±0.5%, metal	74221-2770
R204	Res., 1M, 1/2W, ±0.5%, metal	74221-2340
R205	Res., 800k, 1/2W, ±0.5%, metal	74221-2420
R206	Res., 250k, 1/2W, ±0.5%, metal	74221-2430
R207	Res., 900k, 1/2W, ±0.5%, metal	74221-2310
R208	Res., 111k, 1/4W, ±0.5%, metal	74221-2800
R209	Res., 990k, 1/2W, ±0.5%, metal	74221-2320
R210	Res., 10.1k, 1/4W, ±0.5%, metal	74221-2790
R211	Res., 999k, 1/2W, ±0.5%, metal	74221-2330
R212	Res., 1k, 1/4W, ±0.5%, metal	74221-3110
R230	Res., 100k, 1/4W, ±1%, carbon	74226-2020
R231	Res., 900k, 1/4W, ±1%, carbon	74226-0100
R251	Same as R201	
R252	Same as R201	
R253	Same as R203	
R254	Same as R204	
R255	Same as R205	
R256	Same as R206	
R257	Same as R207	
R258	Same as R208	
R259	Same as R209	
R260	Same as R210	
R261	Same as R211	
R262	Same as R212	
R280	Same as R230	
R281	Same as R231	

TRIGGER GENERATOR

CIRCUIT REFERENCE	DESCRIPTION	IWATSU PART No.
C301	Cap., 0.01μF, 500WV, +80 -20%, cer.	74060-0730
C302	Cap., 0.01μF, 25WV, +80 -20%, cer.	74060-0560
C303	Cap., 33μF, 16WV, -10 +100%, elect.	74120-3080
C305	Cap., 22pF, 50WV, ±10%, cer.	74050-3050
C306	Cap., 33μF, 16WV, ±20%, elect. Tan.	74120-0300
C307	Same as C303	
C308	Cap., 4700pF, 50WV, ±20%, cer.	74060-1660
C350	Cap., 10μF, 10WV, -10 +100%, elect.	74120-0320
C351	Same as C303	
C352	Cap., 100μF, 6.3WV, -10 +100%, elect.	74120-1870
C353	Cap., 2pF, 50WV, ±0.5pF, cer.	74050-1690
C355	Same as C352	
C356	Cap., 0.02μF, 25WV, +80 -20%, cer.	74060-0570
C358	Cap., 10pF, 50WV, ±1pF, cer.	74050-1700
C359	Cap., 12pF, 350WV, var.	74110-0080
C360	Cap., 0.1μF, 25WV, +80 -20%, cer.	74060-2330
C361	Cap., 20pF, 50WV, ±5%, cer.	74050-5280
R301	Res., 1M, 1/2W, ±2%, carbon	74241-1130
R302	Same as R301	
R303	Res., 47, 1/4W, ±20%, compo.	74253-0750
R304	Res., 22, 1/4W, ±20%, compo.	74253-0700
R305	Res., 5k, var. (EXT HORIZ DC BAL), carbon	74349-0320
R306	Res., 5.1k, 1/4W, ±5%, carbon	74223-2060
R307	Res., 100k, 1/4W, ±5%, carbon	74223-2290
R308	Same as R306	
R309	Same as R307	
R310	Res., 1k, 1/4W, ±5%, carbon	74223-1900
R311	Res., 1.5k, 1/4W, ±5%, carbon	74223-1930
R312	Same as R311	
R313	Same as R304	
R314	Res., 3k, 1/4W, ±5%, carbon	74223-1990
R315	Same as R310	
R316	Res., 8.2k, 1/4W, ±5%, carbon	74223-2110
R317	Res., 12k, 1/4W, ±5%, carbon	74223-2150
R318	Res., 3.3k, 1/4W, ±5%, carbon	74223-2000
R319	Res., 2.7k, 1/4W, ±5%, carbon	74223-1980
R320	Same as R304	
R321	Res., 100, 1/4W, ±20%, compo.	74253-0850
R322	Res., 3.9k, 1/4W, ±5%, carbon	74223-2020
R323	Res., 50k, var. (LEVEL CENT)	74349-0220
R324	Res., 5.6k, 1/4W, ±5%, carbon	74223-2070
R325	Res., 47k, 1/4W, ±5%, carbon	74223-2240
R326	Res., 50k, var. (LEVEL AUTO), carbon with S304a, b	74325-2690
R327	Same as R304	

CIRCUIT REFERENCE	DESCRIPTION	IWATSU PART No.
R350	Res., 5.6, 1/4W, ±20%, compo.	74253-1680
R351	Res., 6.8k, 1/4W, ±5%, carbon	74223-2090
R352	Res., 2.4k, 1/4W, ±5%, carbon	74223-1970
R353	Res., 1.3k, 1/4W, ±5%, carbon	74223-1920
R354	Same as R324	
R355	Same as R350	
R356	Same as R310	
R357	Res., 110, 1/4W, ±2%, carbon	74244-0630
R358	Res., 1k, var, carbon	74349-0330
R359	Res., 2.4k, 1/4W, ±2%, carbon	74244-0550
R359b	Same as R321	
R360	Same as R321	
R361	Res., 270k, 1/2W, ±2%, carbon	74241-0990
R362	Res., 820k, 1/2W, ±2%, carbon	74241-1110
R363	Same as R307	
D301	Diode, 1S953	74040-1720
D302	Same as D301	
D303	Same as D301	
D304	Same as D301	
TR301	FET, MK-10-2	74030-3610
TR302	Transistor, XA495C/D	74030-5220
TR303	Same as TR302	
TR304	Transistor, 2SC321 Ⓗ B	74030-4500
TR305	Same as TR304	
TR350	Same as TR304	
TR351	Same as TR304	
TR352	Same as TR304	
S301	Slide switch (SOURCE)	74430-0430
S302	Same as S301 (COUPLING)	
S303	Slide switch (SLOPE)	74430-0440
S304a	Reference R326	
S304b	Reference R326	
T301	Pulse transformer	74400-4690

SAWTOOTH GENERATOR

C401	Cap., 470pF, 500WV, +80 -20%, cer.	74060-2540
C402	Cap., 22pF, 50WV, ±10%, cer.	74050-3050
C403	Cap., 33μF, 16WV, -10 +100%, elect.	74120-3080
C404	Cap., 100μF, 10WV, -10 +100%, elect.	74120-0870
C405	Cap., 100pF, 50WV, ±10%, cer.	74050 1710
C406	Cap., 0.01μF, 25WV, +80 -20%, cer.	74060-0560
C407	Same as C406	
C408	Cap., 15pF, 50WV, ±10%, cer.	74050-1730
C410	Same as C402	
C411	Same as C402	
C412	Same as C403	
C413	Cap., 10μF, 16WV, -10 +100%, elect.	74120-3110
C505b	Cap., 75pF, 50WV, ±5%, cer.	74050-5910
C510	Cap., 10μF, -10 +100%, elect.	74120-3110
C511	Cap., 1μF, 50WV, -10 +100%, elect.	74120-0970
C512	Cap., 0.1μF, 630WV, ±20%, poly.	74130-2820
C513	Cap., 0.01μF, 500WV, -0 +100%, cer.	74060-0340
C513b	Same as C513	
C514	Cap., 1000pF, 50WV, +80 -20%, cer.	74060-1750
C515	Cap., 470pF, 500WV, +80 -20%, cer.	74060-2540
C516	Cap., 100pF, 50WV, +80 -20%, cer.	74050-1710
R401	Res., 3.3k, 1/4W, ±5%, carbon	74223-2000
R402	Res., 220, 1/4W, ±5%, carbon	74223-2470
R403	Res., 5k, var.	74349-0330
R404	Res., 1.8k, 1/4W, ±5%, carbon	74223-1940
R405	Res., 130, 1/4W, ±5%, carbon	74223-3410
R407	Res., 3.6k, 1/4W, ±5%, carbon	74223-2010
R408	Res., 1k, 1/4W, ±5%, carbon	74223-1900
R409	Res., 680, 1/4W, ±5%, carbon	74223-2550
R410	Res., 10, 1/4W, ±20%, compo.	74253-0650
R411	Same as R407	
R412	Same as R409	
R413	Res., 270, 1/4W, ±5%, carbon	74223-2700
R414	Res., 91, 1/4W, ±5%, compo.	74253-0840
R415	Res., 2.2k, 1/4W, ±5%, carbon	74223-1960
R416	Res., 100, 1/4W, ±20%, compo.	74253-0850
R417	Res., 47, 1/4W, ±20%, compo.	74253-0750
R418	Res., 22, 1/4W, ±20%, compo.	74253-0770
R419	Same as R409	
R420	Res., 7.5k, 1/4W, ±5%, carbon	74223-2100
R421	Same as R418	
R422	Res., 4.7, 1/4W, ±20%, compo.	74253-0670
R423	Res., 7.5k, 1/2W, ±2%, carbon	74241-0630
R424	Same as R418	
R426	Res., 5.6k, 1/4W, ±5%, carbon	74223-2070
R427	Res., 18k, 1/4W, ±5%, carbon	74223-2690
R428	Res., 2k, var., carbon	74349-0270
R429	Res., 20k, 1/4W, ±5%, carbon	74223-2170
R430	Res., 5.1k, 1/4W, ±5%, carbon	74223-2060
R431	Res., 1M, 1/2W, ±2%, carbon	74241-1130
R433	Res., 15k, 1/4W, ±5%, carbon	74223-3680
R434	Res., 4.7k, 1/4W, ±5%, carbon	74223-2040
R435	Same as R410	
R436	Same as R427	
R437	Same as R401	
R438	Same as R410	
R439	Res., 30k, 1/4W, ±5%, carbon	74223-2210
R440	Same as R420	
R441	Same as R408	
R442	Same as R409	
R443	Res., 6.5k, 1/4W, ±1%, carbon	74212-0380
R444	Res., 2k, 1/4W, ±5%, carbon	74223-1950

CIRCUIT REFERENCE	DESCRIPTION	IWATSU PART No.
R449	Same as R410	
R450	Same as R444	
R451	Same as R407	
R501	Res., 3.6M, 1/8W, ±1%, metal	74221-3040
R502	Res., 1.2M, 1/8W, ±1%, metal	74221-3030
R503	Res., 600k, 1/4W, ±1%, metal	74221-2440
R504	Res., 360k, 1/4W, ±1%, metal	74221-3070
R505	Res., 240k, 1/4W, ±1%, metal	74221-3060
R506	Res., 120k, 1/4W, ±1%, metal	74221-3050
R507	Res., 60k, 1/4W, ±1%, metal	74221-3080
R508	Res., 13k, 1/4W, ±5%, carbon	74223-3350
R509	Res., 20k + 5k, var., (VARIABLE), carbon	74325-1840
R510	Res., 75k, 1/2W, ±2%, carbon	74241-0860
D401	Diode, 1S953	74050-1720
D402	Same as D401	
D403	Same as D401	
D404	Diode, 1S1761	74040-3160
D405	Same as D401	
D406	Same as D401	
D407	Same as D401	
D410	Same as D401	
TR401	Transistor, 2SC321 Ⓗ B	74030-4500
TR402	Transistor, XA495C/D	74030-5220
TR403	Same as TR401	
TR404	FET, MK-10-2D	74030-3870
TR405	Same as TR401	
TR406	Same as TR401	
TR407	Same as TR401	
TR408	Same as TR401	
TR409	Same as TR401	
S401	Push-button switch (PUSH FREERUN)	74430-0090
S402	Rotary switch (TIME/CM)	74431-6120

TIMING SWITCH

C501	Cap., 1μF, 50WV, +0 -2%, poly.	74130-2270
C502	Cap., 0.1μF, 50WV, +0 -2%, poly.	74130-2190
C503	Cap., 0.01μF, 50WV, ±1%, poly.	74130-3870
C504	Cap., 0.001μF, 50WV, ±1%, poly.	74130-3880
C505a	Cap., 25pF, 350WV, var.	74110-0110
C506	Same as C505a	
C507	Cap., 82pF, 50WV, ±10%, cer.	74050-4730

HORIZONTAL AMPLIFIER

C601	Cap., 25pF, 350WV, var.	74110-0110
C602	Cap., 4pF, 500WV, var.	74110-0300
C603	Cap., 1pF, 50WV, ±0.5pF, cer.	74050-4770
C604	Cap., 0.1μF, 25WV, +80 -20%, cer.	74060-2330
C605	Cap., 100μF, 16WV, -10 +100%, elect.	74120-3020
C606	Same as C602	
C607	Same as C604	
C608	Same as C605	
C609	Cap., 22pF, 50WV, ±10%, cer.	74050-3050
C610	Cap., 82pF, 50WV, ±10%, cer.	74050-4730
C612	Cap., 47μF, 200WV, -10 +100%, elect.	74120-0280
C620	Cap., 680pF, 300WV, ±5%, mica	74090-5130
C630	Cap., 1000pF, 50WV, +80 -20%, cer.	74060-1750
R601	Res., 50k, var., carbon	74349-0220
R602	Res., 130k, 1/4W, ±5%, carbon	74223-3270
R603	Res., 36k, 1/4W, ±1%, carbon	74212-2300
R604	Res., 145k, 1/4W, ±1%, carbon	74212-1350
R605	Res., 430k, 1/4W, ±5%, carbon	74223-2360
R606	Res., 50k, var. (position), carbon, with S601	74323-0520
R607	Res., 620, 1/4W, ±5%, carbon	74223-2540
R608	Res., 22, 1/4W, ±20%, compo.	74253-0700
R609	Res., 62k, 1/4W, ±5%, carbon	74223-2260
R610	Res., 3k, var., carbon	74349-0480
R611	Res., 10k, 1/4W, ±5%, carbon	74223-2130
R612	Res., 3k, 1/4W, ±5%, carbon	74223-1990
R613	Res., 10, 1/4W, ±20%, compo.	74253-0650
R614	Res., 5.6, 1/4W, ±20%, compo.	74253-1680
R615	Res., 750, 1/4W, ±5%, carbon	74223-2570
R616	Res., 43k, 1/4W, ±5%, carbon	74223-2230
R618	Res., 100, 1W, ±2%, carbon	74242-0120
R619a	Res., 20k, 2W, ±2%, carbon	74243-0630
R619b	Same as R619a	
R620	Res., 18k, 2W, ±2%, carbon	74243-0620
R621	Res., 430, 1/4W, ±5%, carbon	74223-2510
R622	Res., 680, 1/2W, ±2%, carbon	74241-0400
R632	Res., 470, 1/4W, ±5%, carbon	74223-2630
R633	Res., 5k, var., carbon	74349-0320
R634	Res., 7.5k, 1/4W, ±5%, carbon	74223-2100
TR601	Transistor, 2SC321 Ⓗ B	74030-4500
TR602	Transistor, XA495C/D	74030-5220
TR603	Same as TR602	
TR604	Transistor, 2SC154C	74030-4000
TR605	Same as TR604	
S601	Reference R606	
RL601	Relay, SM-12	74450-0640

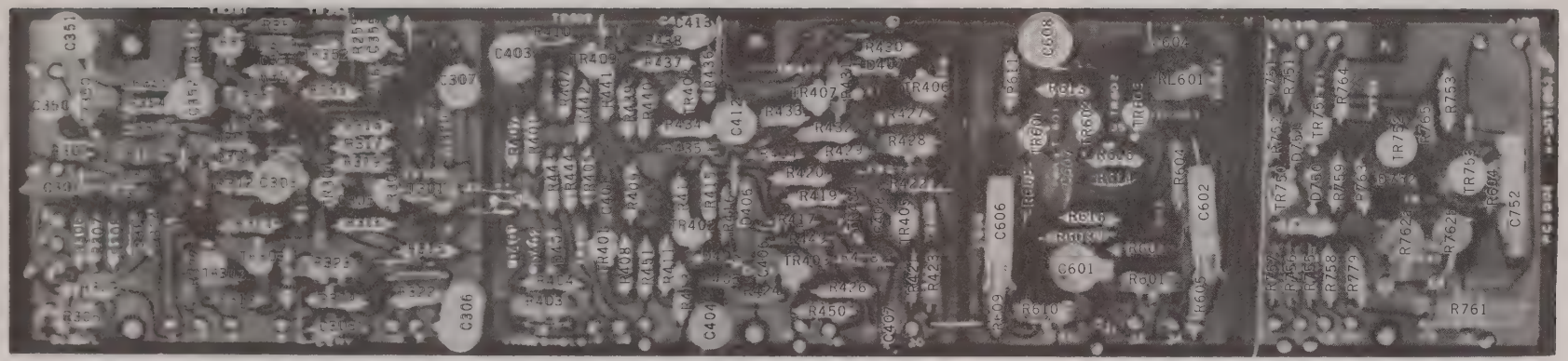
CRT CIRCUIT & Z AMP

CIRCUIT REFERENCE	DESCRIPTION	IWATSU PART No.
C701	Cap., 0.22μF, 250WV, ±20%, poly.	74130-4660
C701b	Cap., 0.01μF, 50WV, +80 -20%, cer.	74060-0580
C702	Cap., 4700pF, 500WV, -0 +100%, cer.	74060-0270
C703	Cap., 5000pF, 3kWV, -0 +100%, cer.	74060-2750
C704	Same as C703	
C705a	Same as C703	
C705b	Cap., 0.015μF, 2.5kWV, +80 -20%, cer.	74060-1960
C706	Cap., 0.1μF, 25WV, +80 -20%, cer.	74060-2330
C707	Same as C703	
C708	Same as C705b	
C709	Same as C703	
C710	Cap., 100μF, 25WV, -10 +100%, elect.	74120-0880
C751	Same as C701b	
C752	Cap., 1pF, 50WV, cer.	74050-4770
C753	Cap., 33μF, 250WV, -10 +100%, elect.	74120-0290
C754	Same as C706	
R701	Res., 100k, var., carbon	74349-0350
R702	Res., 3M, 1/4W, ±5%, compo.	74281-0050
R703	Res., 1.8M, 1/4W, ±5%, compo.	74253-1670
R704	Res., 10k, 1/4W, ±5%, carbon	74223-2130
R705	Res., 100k, 1/4W, ±5%, carbon	74223-2290
R706	Res., 2.4k, 1/4W, ±5%, carbon	74223-1970
R707	Res., 12k, 1/4W, ±5%, carbon	74223-2150
R710	Res., 82k, 1/4W, ±5%, carbon	74223-3420
R711	Res., 10, 1/4W, ±20%, compo.	74253-0650
R712	Same as R705	
R713	Res., 1k, 1/4W, ±5%, carbon	74223-1900
R714	Res., 430k, 1/4W, ±5%, carbon	74223-2360
R715	Res., 12k, 1/4W, ±5%, carbon	74223-2150
R716	Res., 33k, 1/4W, ±5%, carbon	74223-3240
R717a	Res., 2.2M, 1/2W, ±5%, compo.	74254-0720
R717b	Same as R717a	
R717c	Same as R717a	
R717d	Res., 3M, 1/2W, ±5%, compo.	74254-0640
R718	Res., 1M, 1/2W, ±10%, compo.	74254-0170
R720	Res., 10k, var., carbon	74349-0370
R721	Res., 4.7k, 1/4W, ±5%, carbon	74223-2040
R722	Res., 75k, 1/4W, ±5%, carbon	74223-2280
R723	Res., 200k, var., carbon	74323-0510
R724	Res., 2M, var. (FOCUS), carbon	74323-0570
R725	Same as R718	
R726	Same as R705	
R727a	Same as R717a	
R727b	Same as R717a	
R730a	Res., 5.6M, 1/2W, ±5%, compo.	74254-0560
R730b	Same as R730a	
R730c	Same as R730a	
R730d	Same as R730a	
R730e	Res., 5.1M, 1/2W, ±5%, compo.	74254-0740
R730f	Same as R730a	
R751	Res., 100, 1/4W, ±20%, compo.	74253-0850
R752	Res., 10k, 1/2W, ±2%, carbon	74241-0660
R753	Same as R722	
R754	Same as R713	
R755	Res., 47, 1/4W, ±20%, compo.	74253-0750
R756	Same as R755	
R757	Same as R755	
R758	Res., 2.7k, 1/4W, ±5%, carbon	74223-1980
R759	Res., 3k, 1/4W, ±5%, carbon	74223-1990
R760	Res., 39k, 1/2W, ±2%, carbon	74241-0790
R761	Res., 1.5k, 2W, ±2%, carbon	74243-0370
R762a	Res., 18k, 2W, ±2%, carbon	74243-0620
R762b	Same as R762a	
R763	Res., 36, 1/2W, ±2%, carbon	74241-0100
R764	Res., 100, 1/4W, ±5%, carbon	74223-3190
R765	Res., 47k, 1/2W, ±2%, carbon	74241-0810
R779	Res., 3.9k, 1/4W, ±5%, carbon	74223-2020
R779b	Res., 47k, 1/4W, ±5%, carbon	74223-2240
R780	Res., 10k, var. (INTENSITY), carbon	74323-0510
D701	Rectifier, HS6/1	74040-3990
D702	Same as D701	
D703	Diode, HFSD-1	74040-3140
D750	Diode, 1S953	74040-1720
D751	Same as D750	
D752	Same as D750	
TR704	Transistor, 2SD224Y	74030-4680
TR750	Transistor, 2SC321 Ⓗ B	74030-4500
TR751	Same as TR750	
TR752	Transistor, 2SC154C	74030-4000
TR753	Same as TR752	
IC701	Integrated circuit, A-2	74570-0020
T701	High voltage transformer	74472-1150
TB750	Terminal, 9.5φ (Z AXIS IN)	74510-0090
TB751	Same as TB750 (GND)	
V701	Cathode-ray tube, 5DEP1(F)	74010-1070
	or 130ARB1	74010-1270
F701	Fuse, 1A (6.3φ x 30*l*)	74540-0060

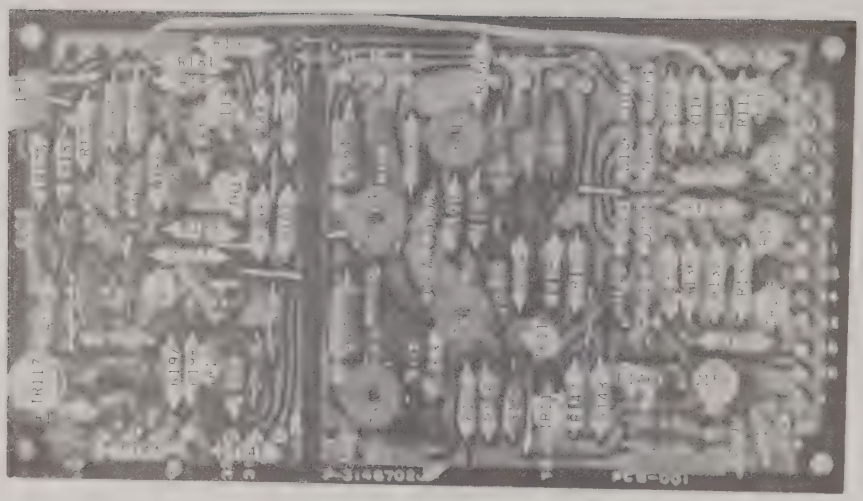
POWER SUPPLY & CAL

C801	Cap., 100μF, 200WV, -10 +100%, elect.	74120-2010
C802	Cap., 0.01μF, 50WV, +80 -20%, cer.	74060-0580
C803	Same as C802	

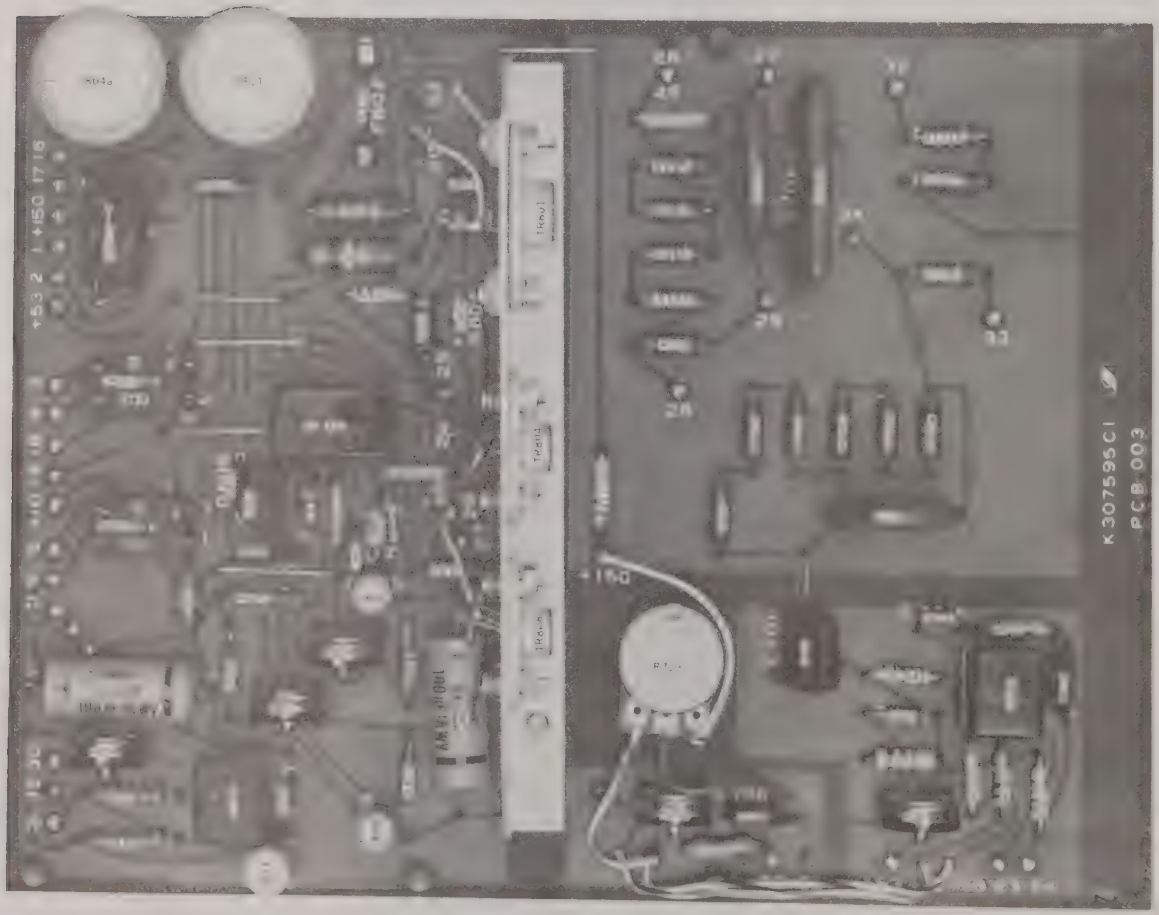
CIRCUIT REFERENCE	DESCRIPTION	IWATSU PART No.
C804a	Cap., 1000μF, 25WV, -10 +100%, elect.	74120-0120
C804b	Same as C802	
C805	Cap., 10μF, 16WV, -10 +100%, elect.	74120-3110
C806	Cap., 100μF, 16WV, -10 +150%, elect.	74120-3340
C807	Cap., 0.1μF, 25WV, +80 -20%, cer.	74060-2330
C808	Same as C807	
C809	Same as C805	
C810	Same as C806	
C811	Same as C804a	
C851	Cap., 47μF, 16WV, -10 +100%, elect.	74120-3090
R801	Res., 100k, 1/4W, ±5%, carbon	74223-2290
R802	Res., 20k, 1W, ±2%, carbon	74242-0590
R803	Res., 10, 1/2W, ±2%, carbon	74241-0010
R804	Res., 510, 1W, ±2%, carbon	74242-0230
R805	Same as R801	
R807	Res., 13k, 1/4W, ±5%, carbon	74223-3350
R808	Res., 100, 1/4W, ±20%, compo.	74253-0850
R811	Res., 4.7k, 1/4W, ±1%, carbon	74212-2240
R812	Res., 5.1k, 1/4W, ±1%, carbon	74212-2160
R813	Res., 1k, var., carbon	74349-0330
R816	Res., 2.4k, 1/4W, ±5%, carbon	74223-1970
R817	Same as R808	
R820	Res., 221k, 1/4W, ±1%, carbon	74212-1430
R821	Res., 3.9k, 1/2W, ±1%, carbon	74213-2300
R822	Res., 2k, var., carbon	74349-0270
R830	Res., 0.5, ±20%, W.W.	74310-2210
R831	Same as R830	
R854	Same as R813	
R855	Res., 45, 1/4W, ±1%, carbon	74212-2210
R856	Res., 5, 1/4W, ±1%, carbon	74212-2200
R857	Res., 4.7, 1/4W, ±20%, compo.	74253-0640
D801	Diode, M4G-1	74040-3980
D802	Diode, M4C-1	74040-3880
D803	Same as D802	
D804	Diode, HW43A	74040-3300
D806	Diode, RD6A	74040-0790
TR801	Transistor, 2SC685	74030-3570
TR804	Transistor, 2SD222	74030-4370
TR808	Same as TR804	
IC801	Integrated circuit, AY-18	74570-0220
IC802	Integrated, circuit, AY-29	74570-0330
S801	Toggle switch	74430-0350
S802	Toggle switch	74430-0370
T801	Power transformer	74471-2160
F801	Fuse, 1A (5.2φ x 20*l*)	74540-0280
F802	Fuse, 0.5A (5.2φ x 20*l*)	74540-0260
NE801	Neon lamp, BNF-3	74020-1770



Printed Circuit Board Diagram (Trigger Amplifier • Sawtooth Generator • Horizontal Amplifier • Z Axis Amplifier)

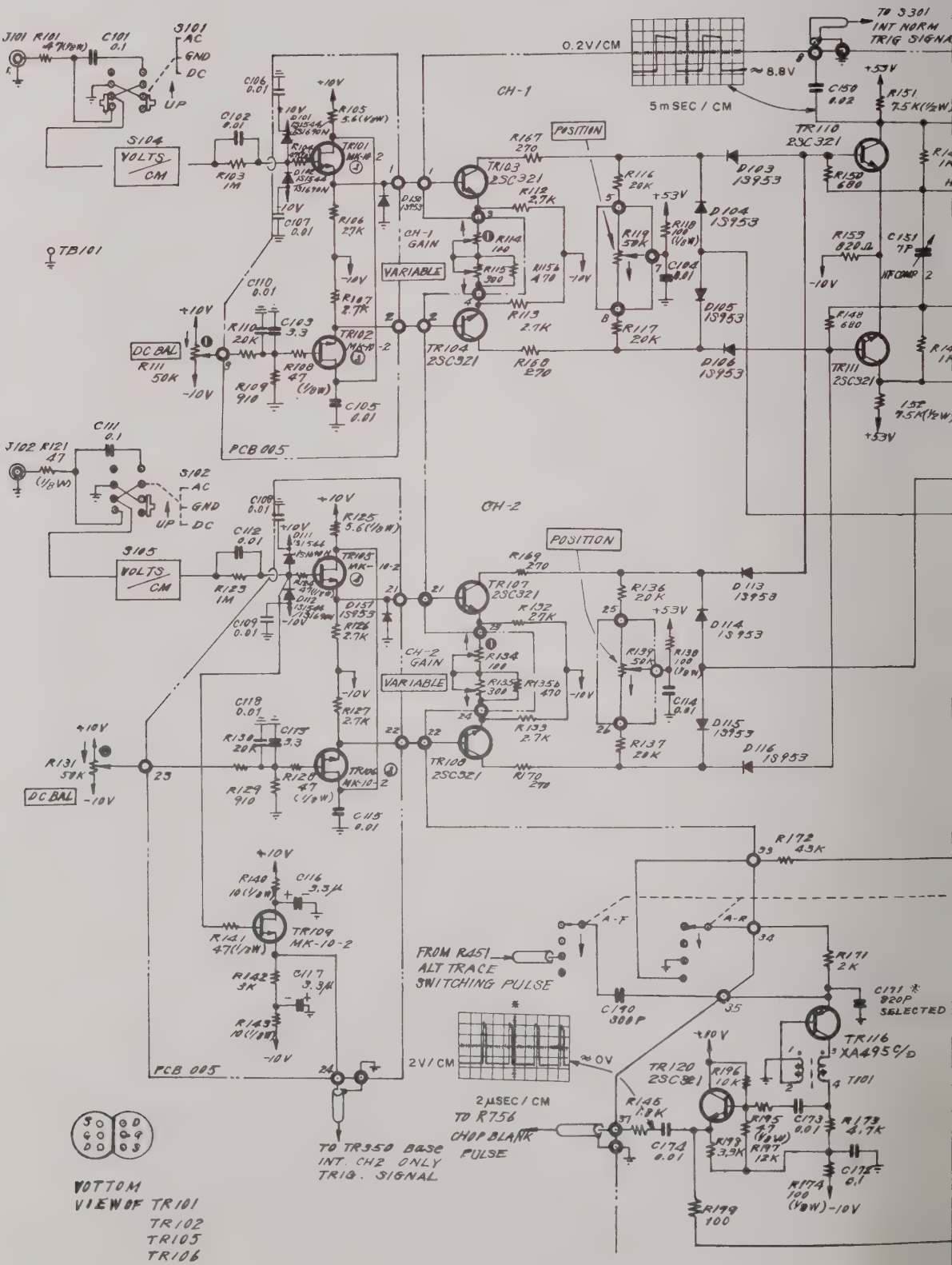


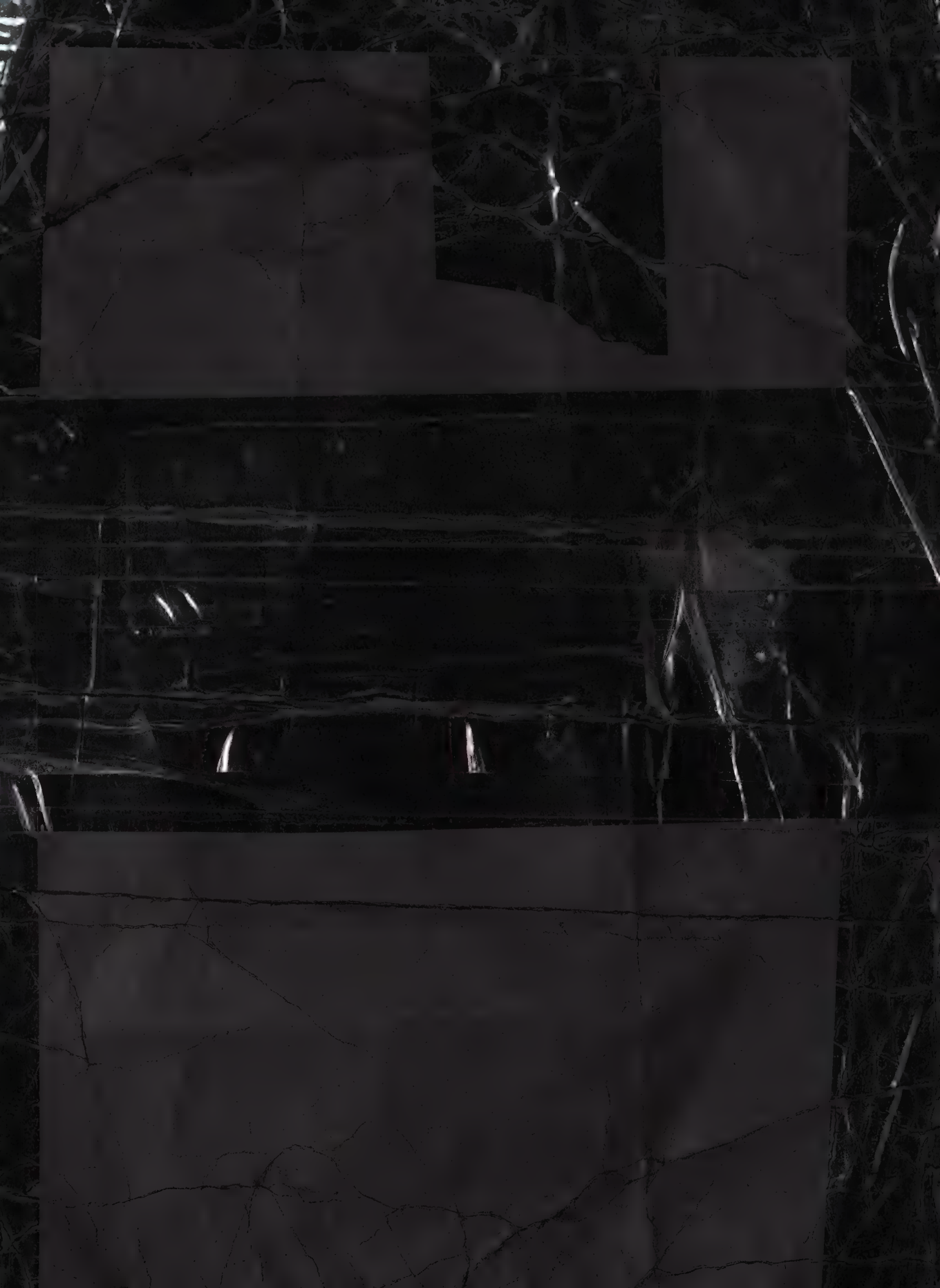
Printed Circuit Board Diagram (Vertical Circuit)

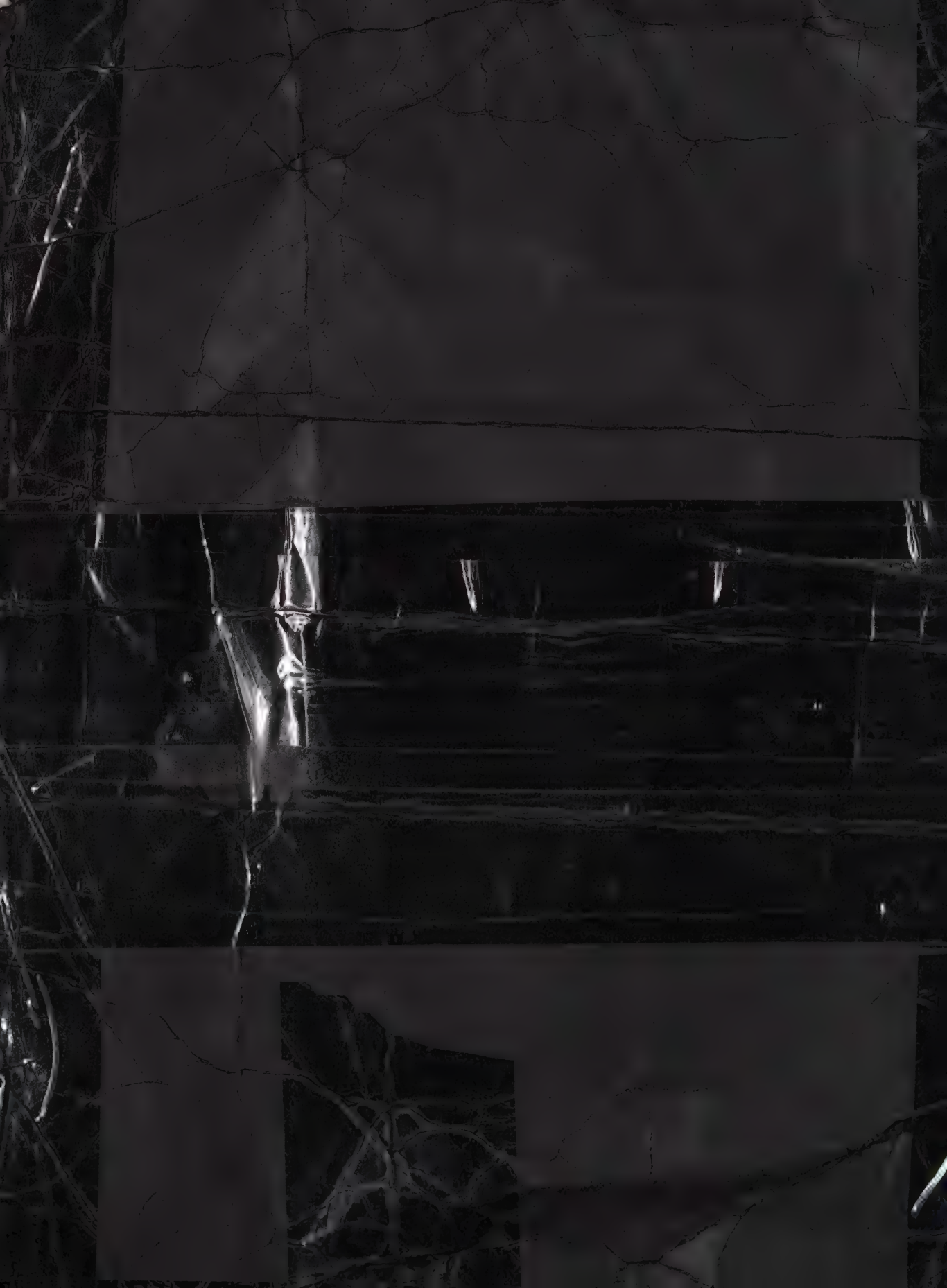


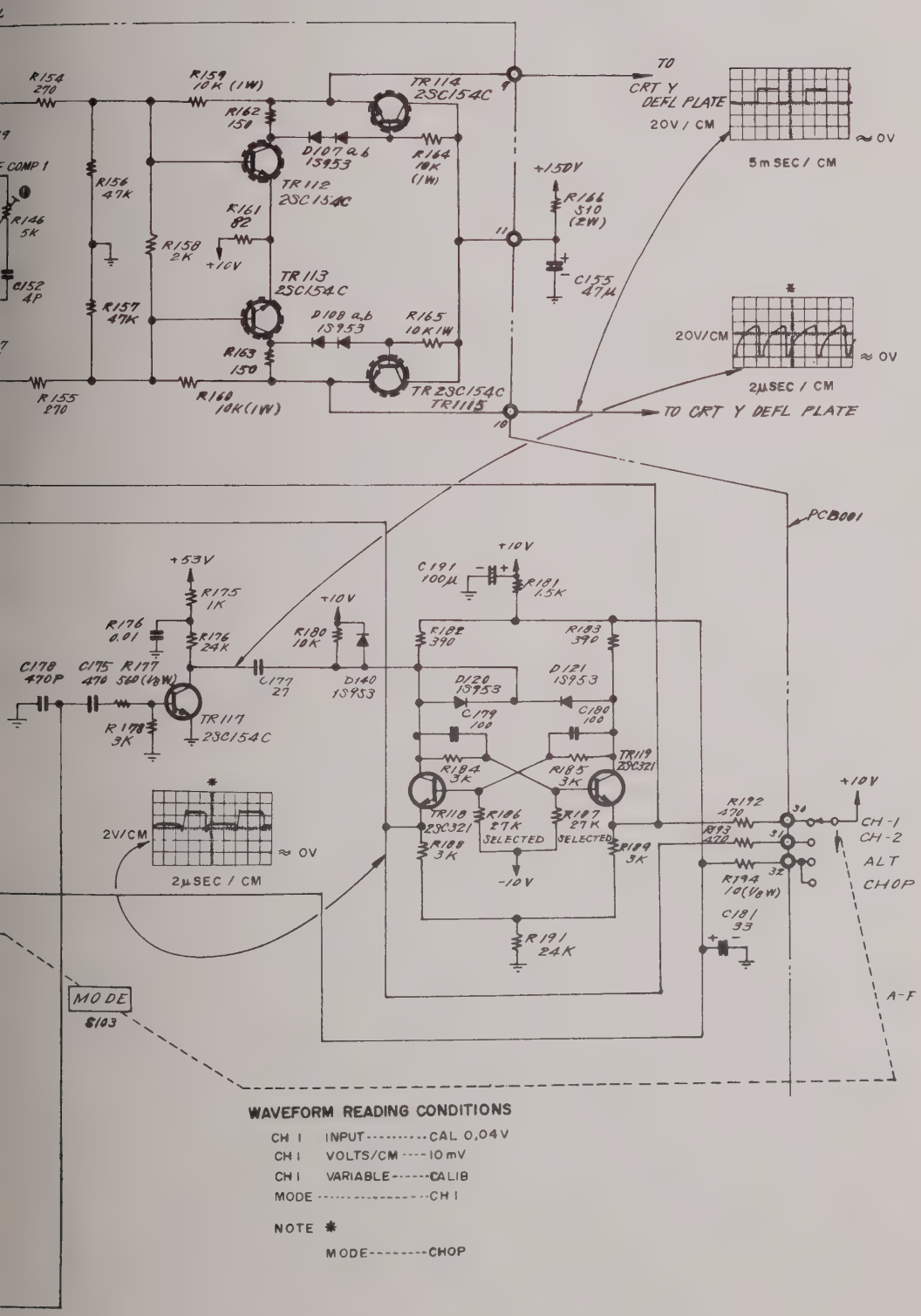
Printed Circuit Board Diagram (CRT Circuit • Low Voltage Power Supply • Caliblator)

VERTICAL AMPLIFIER ➡


J101 R101 47K(1/8W) C101 0.1
S101 AC GND DC UP
S104 VOLTS/CM
C106 0.01
C102 0.01
R103 1M
C107 0.01
C110 0.01
C103 3.3
R110 20K
R108 47 (1/8W)
R109 910
C105 0.01
DC BAL R111 50K
TB101
PCB 005
CH-1
0.2V/CM
≈ 8.8V
5mSEC / CM
TO S301 INT NORM TRIG SIGNAL
C150 0.02
R151 7.5K(1/2W)
+53V
TR110 2SC321
R150 680
R153 820Ω
C151 7P
HF COMP
R148 680
TR111 2SC321
R152 7.5K(1/2W)
POSITION
R167 270
TR103 2SC321
R112 2.7K
R116 20K
D103 1S953
D104 1S953
R118 100 (1/8W)
R119 50K
C104 0.01
D105 1S953
R117 20K
D106 1S953
R168 270
TR104 2SC321
R113 2.7K
R114 100
R115 390
R115b 470
CH-1 GAIN VARIABLE
R106 2.7K
R107 2.7K
C111 0.1
J102 R121 47 (1/8W)
S102 AC GND DC UP
S105 VOLTS/CM
C109 0.01
C112 0.01
R123 1M
R125 5.6(1/8W)
R126 2.7K
R127 2.7K
C118 0.01
C113 3.3
R130 20K
R128 47 (1/8W)
R129 910
C115 0.01
DC BAL R131 50K
CH-2
POSITION
R169 270
TR107 2SC321
R132 2.7K
R136 20K
D113 1S953
D114 1S953
R138 100 (1/8W)
R139 50K
C114 0.01
D115 1S953
R137 20K
D116 1S953
R170 270
TR108 2SC321
R133 2.7K
R134 100
R135 300
R135b 470
CH-2 GAIN VARIABLE
R172 4.5K
A-F
A-R
R171 2K
C171 * 820P SELECTED
C170 300P
FROM R451 ALT TRACE SWITCHING PULSE
2V/CM
≈ 0V
2μSEC / CM
TO R756 CHOP BLANK PULSE
TR116 2SA495 C/D
TR120 2SC321
T101
R196 10K
R195 4.7 (1/2W)
C173 0.01
R173 4.7K
R193 3.5K
R197 12K
C172 0.1
R174 100 (1/2W)
R199 100
R145 10K
C174 0.01
TO TR950 Base INT. CH2 ONLY TRIG. SIGNAL
R140 10(1/2W)
C116 3.3μ
TR109 MK-10-2
R141 47(1/2W)
R142 3K
C117 3.3μ
R143 10(1/2W)
BOTTOM VIEW OF TR101 TR102 TR105 TR106







WAVEFORM READING CONDITIONS

CH I	INPUT	CAL 0.04V
CH I	VOLTS/CM	10mV
CH I	VARIABLE	CALIB
MODE		CH I

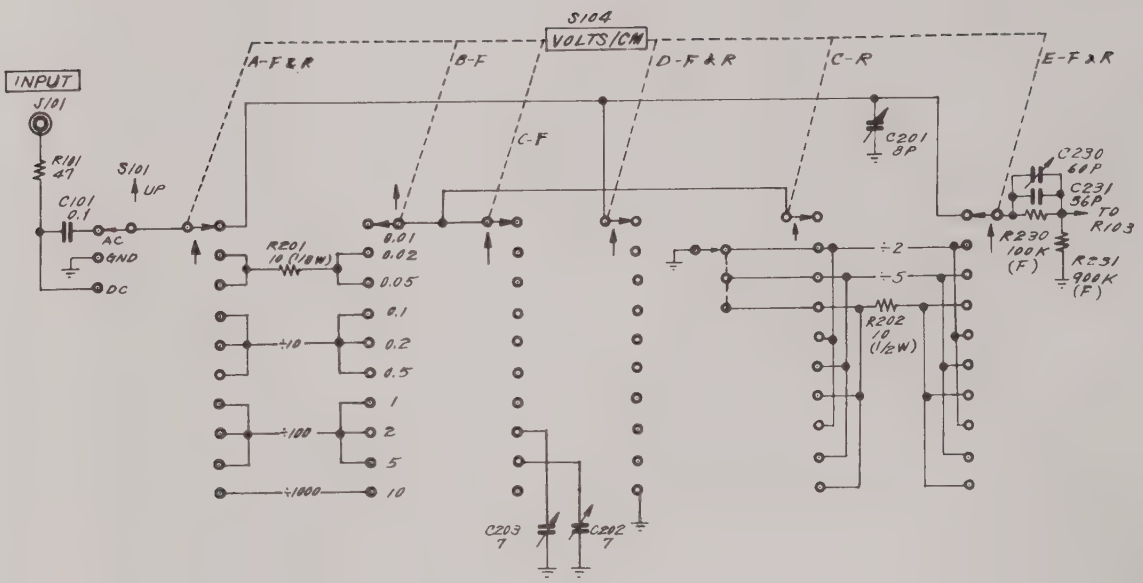
NOTE ✱

MODE --- CHOP

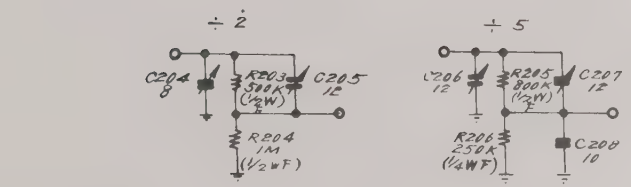
VERTICAL AMPLIFIER

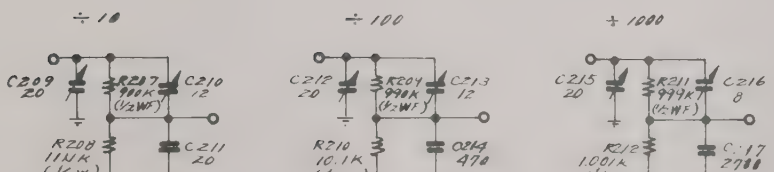
(K−604932−5)

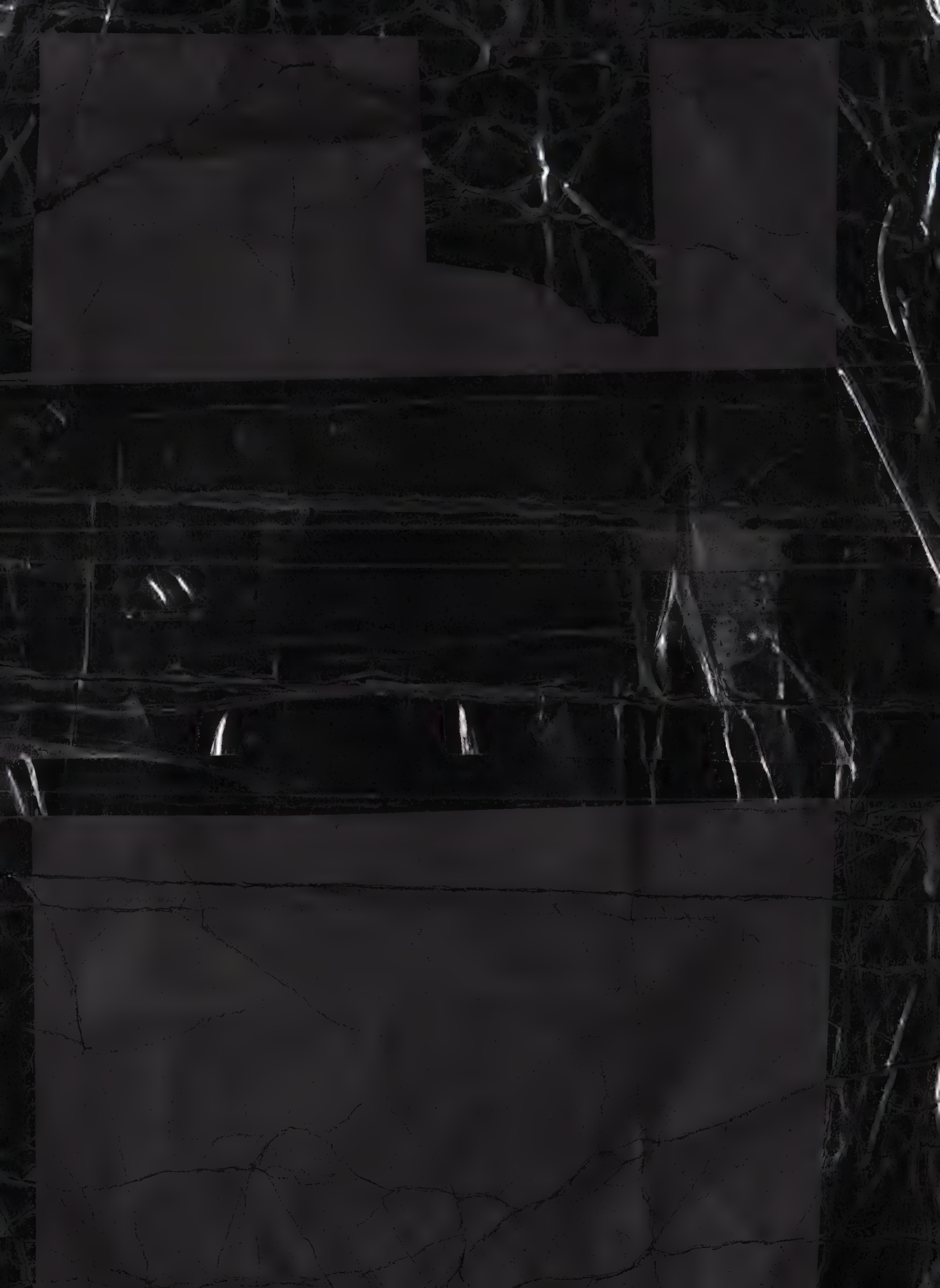
ATTENUATOR DETAIL ➡

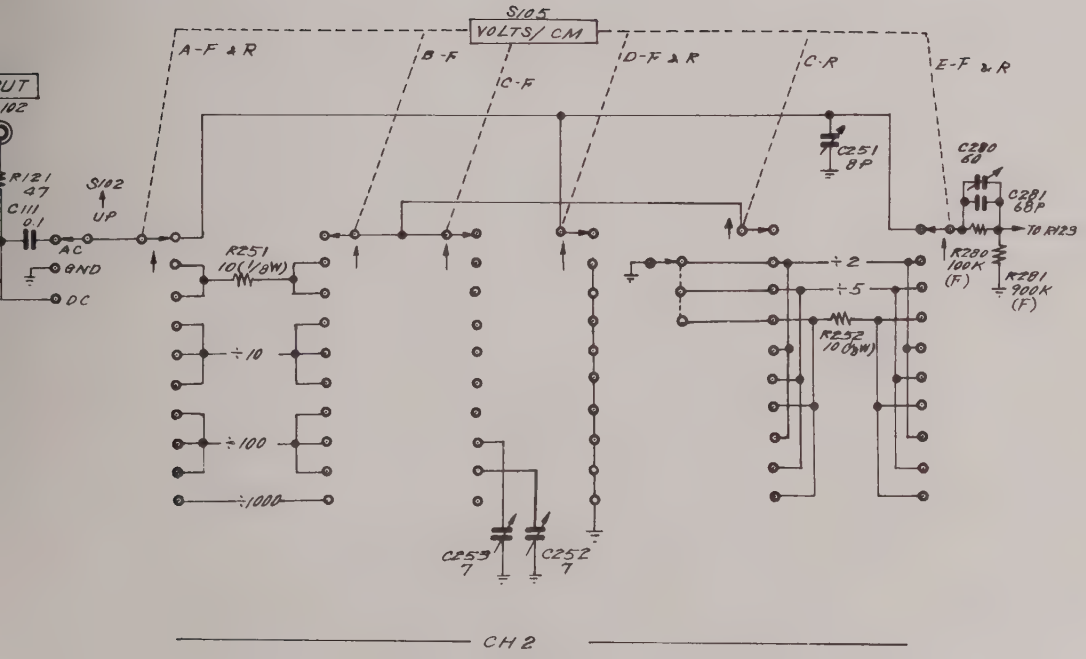

S104
VOLTS/CM
A-F & R
B-F
C-F
D-F & R
C-R
E-F & R
INPUT
J101
R101 47
S101 UP
C101 0.1
AC
GND
DC
R201 10 (1/8W)
0.01
0.02
0.05
÷10
0.1
0.2
0.5
÷100
1
2
5
÷1000
10
C203 7
C202 7
C201 8P
÷2
÷5
R202 10 (1/2W)
C230 60P
C231 36P
TO R103
R230 100K (F)
R231 900K (F)

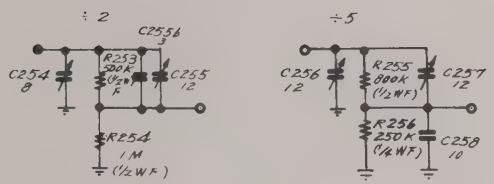
CH 1

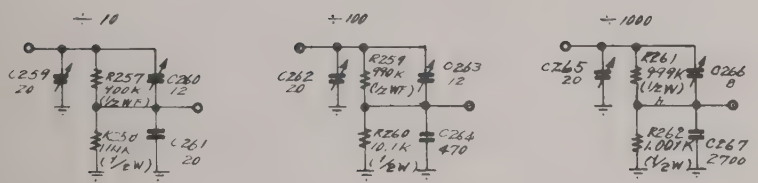

÷ 2
C204 8
R203 500K (1/2W)
C205 12
R204 1M (1/2WF)
÷ 5
C206 12
R205 800K (1/2W)
C207 12
R206 250K (1/4WF)
C208 10


÷ 10
C209 20
R207 990K (1/2WF)
C210 12
R208 11NK (1/2W)
C211 20
÷ 100
C212 20
R209 990K (1/2WF)
C213 12
R210 10.1K (1/2W)
C214 470
÷ 1000
C215 20
R211 999K (1/2WF)
C216 8
R212 1001K (1/2W)
C217 2700





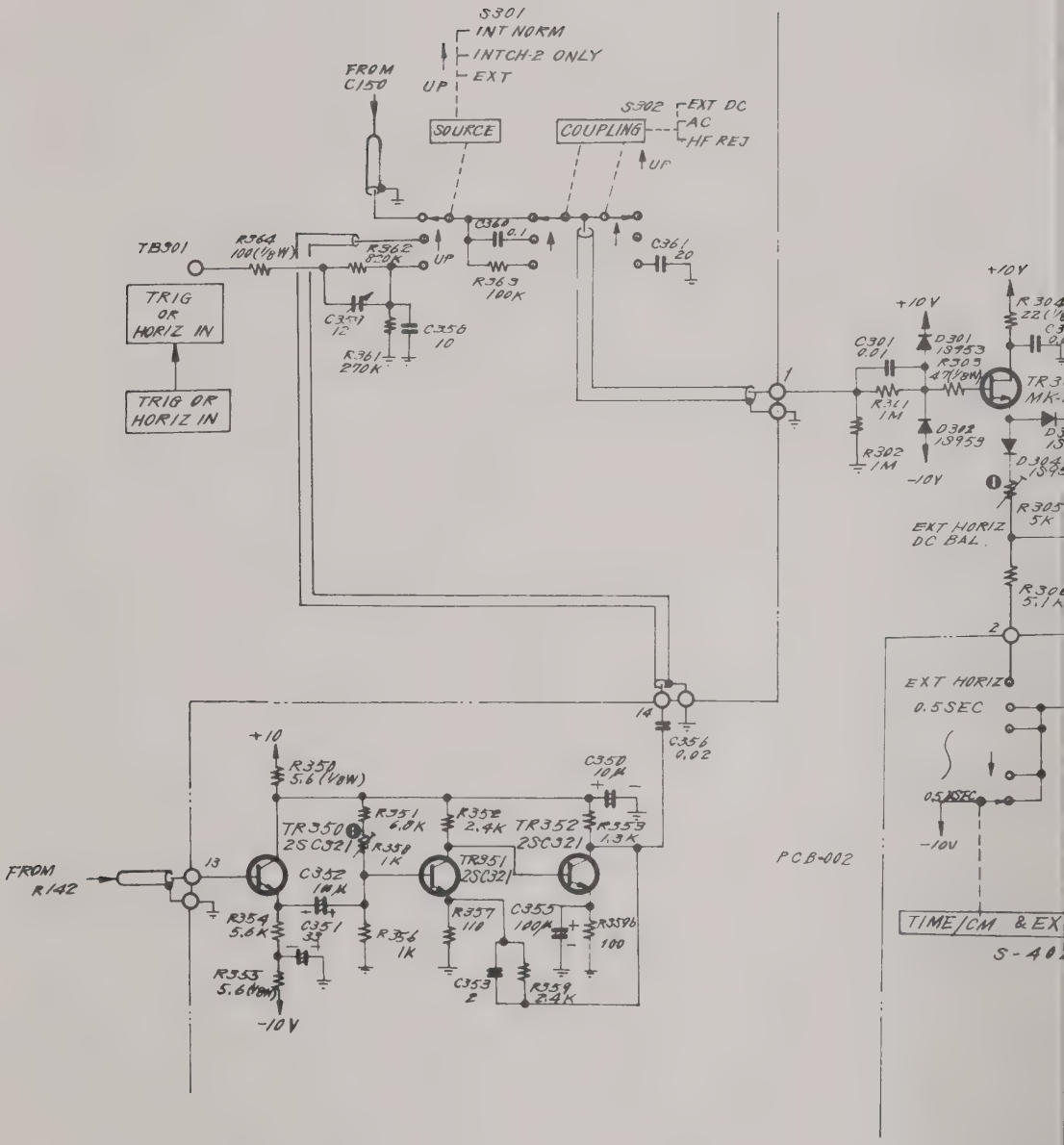


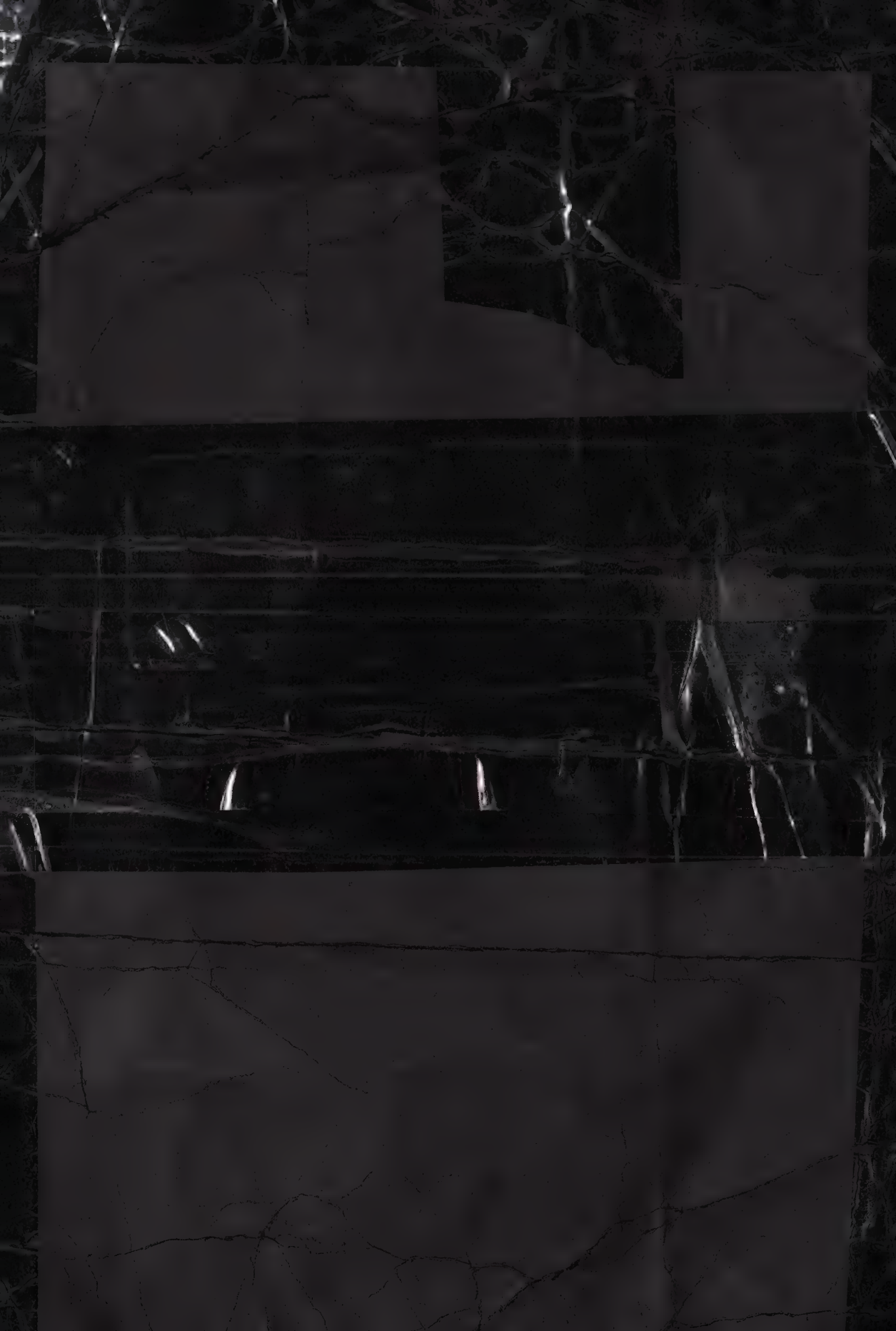


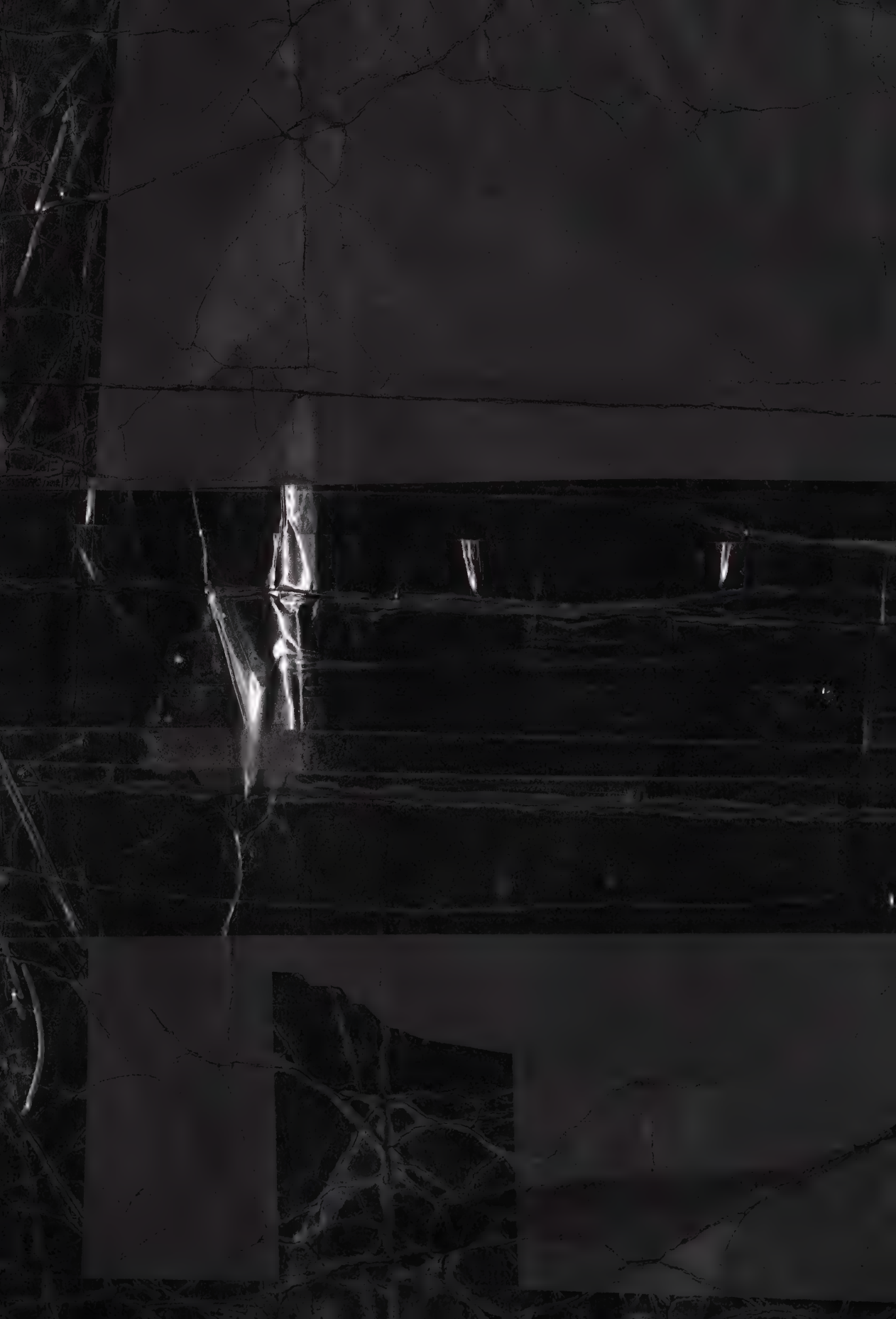
ATTENUATOR DETAIL

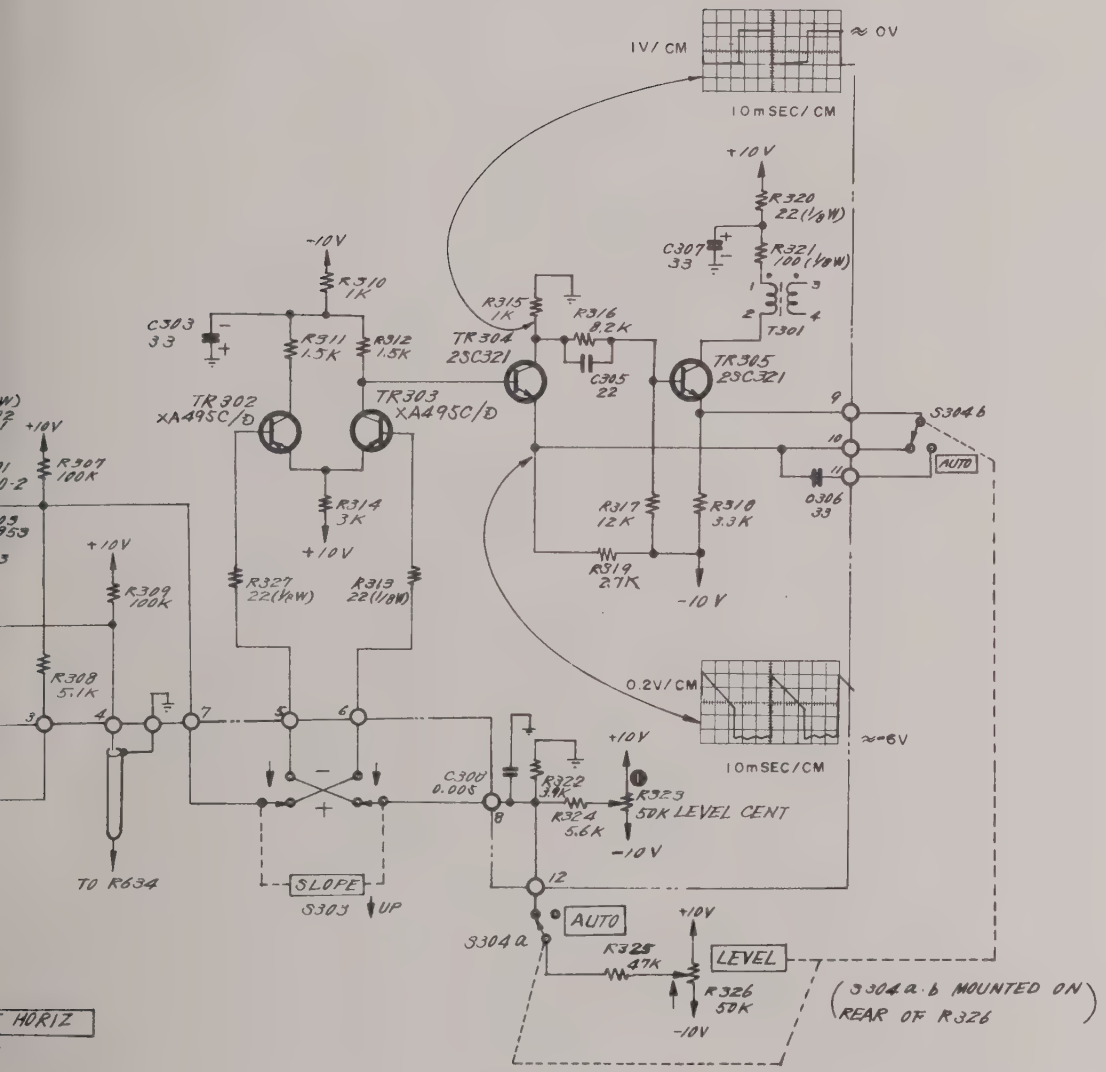
(K-604933-4)

TRIGGER GENERATOR ➡


S301
INT NORM
INTCH-2 ONLY
EXT
FROM C150
UP
SOURCE
COUPLING
S302
EXT DC
AC
HF REJ
UP
TB301
R364 100(1/8W)
R362 8.2K
UP
C360 0.1
R363 100K
C361 20
TRIG OR HORIZ IN
TRIG OR HORIZ IN
C357 12
C358 10
R361 270K
+10V
C301 0.01
D301 1S953
R303 47(1/8W)
R311 1M
D302 1S959
R302 1M
-10V
EXT HORIZ DC BAL.
EXT HORIZ
0.5SEC
-10V
TIME/CM &
+10
R350 5.6(1/8W)
C350 10μ
R351 6.8K
R352 2.4K
R353 1.3K
TR350 2SC321
TR351 2SC321
TR352 2SC321
R358 1K
FROM R142
C352 1MM
R354 5.6K
C351 33
R356 1K
R357 110
C355 100μ
R358 100
R353 5.6(1/8W)
C353 2
R359 2.4K
-10V
C356 0.02
PCB-002







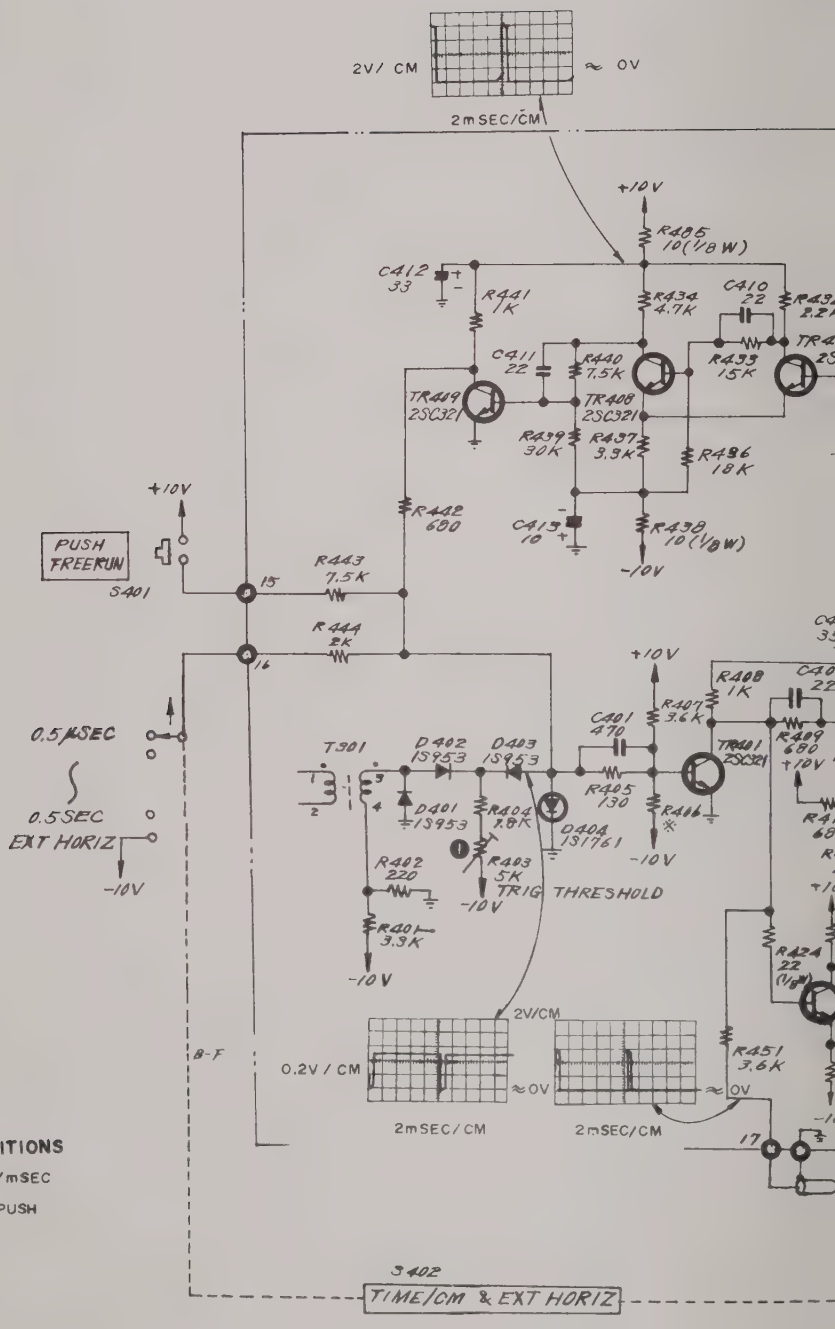
WAVEFORM READING CONDITIONS

LEVEL (& AUTO)-----AUTO

TRIGGER GENERATOR

(K-604934-4)

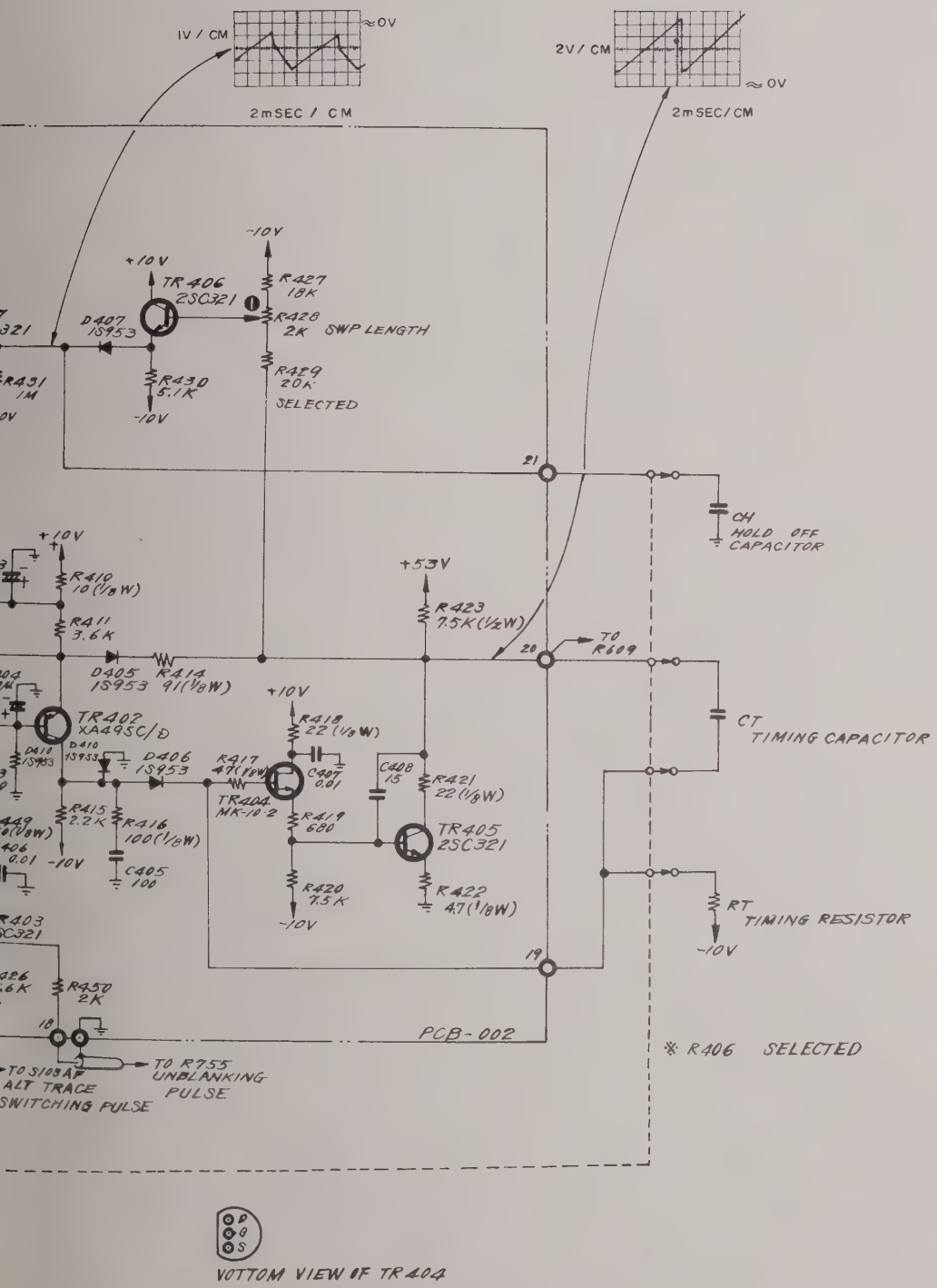
SAWTOOTH GENERATOR ➡



WAVEFORM READING CONDITIONS

TIME / CM ---------- /mSEC

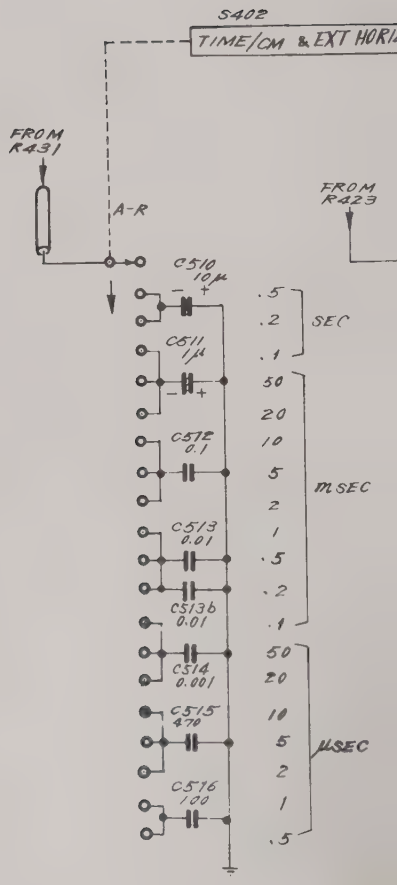
PUSH FREE RUN-----PUSH

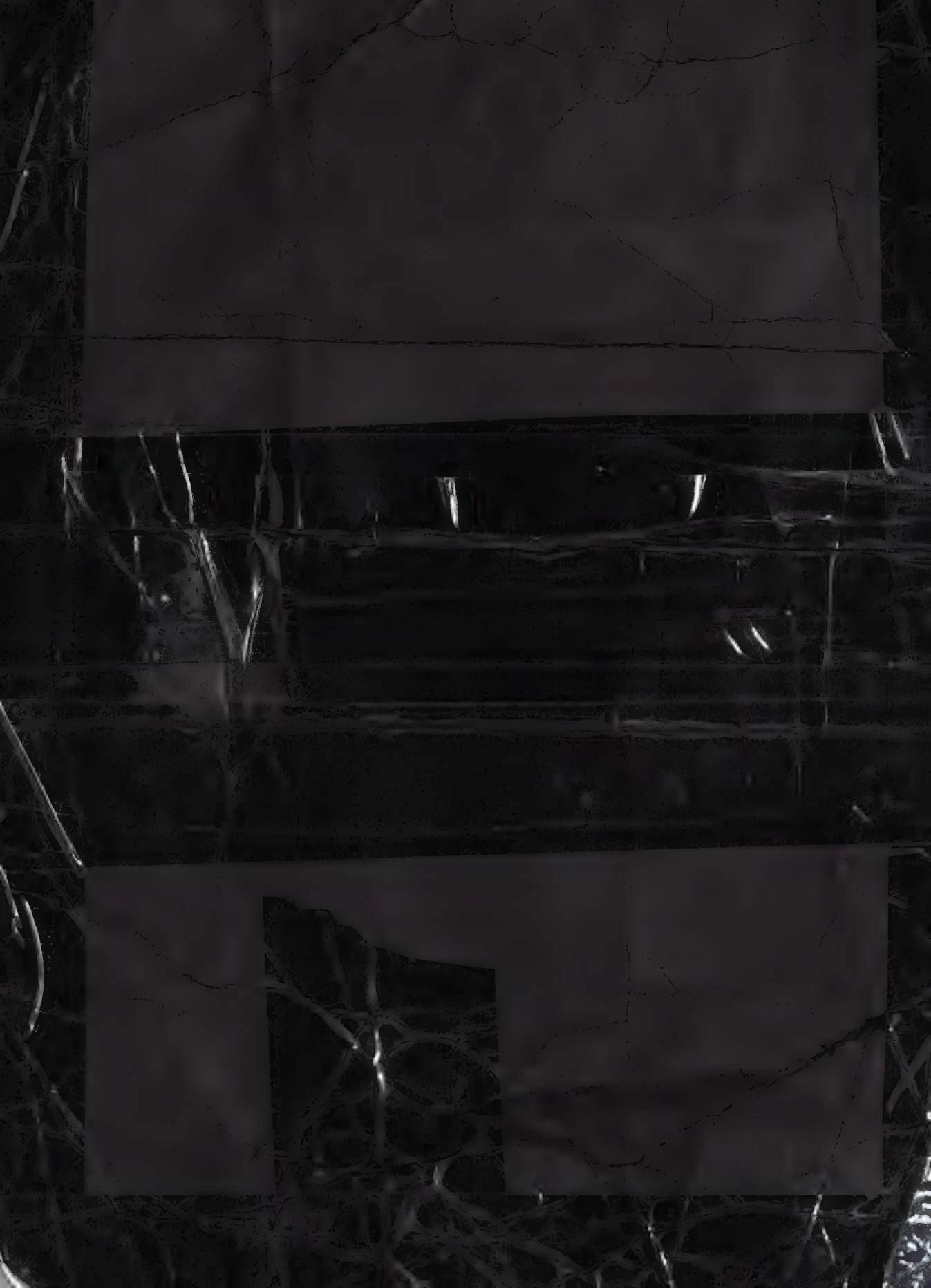


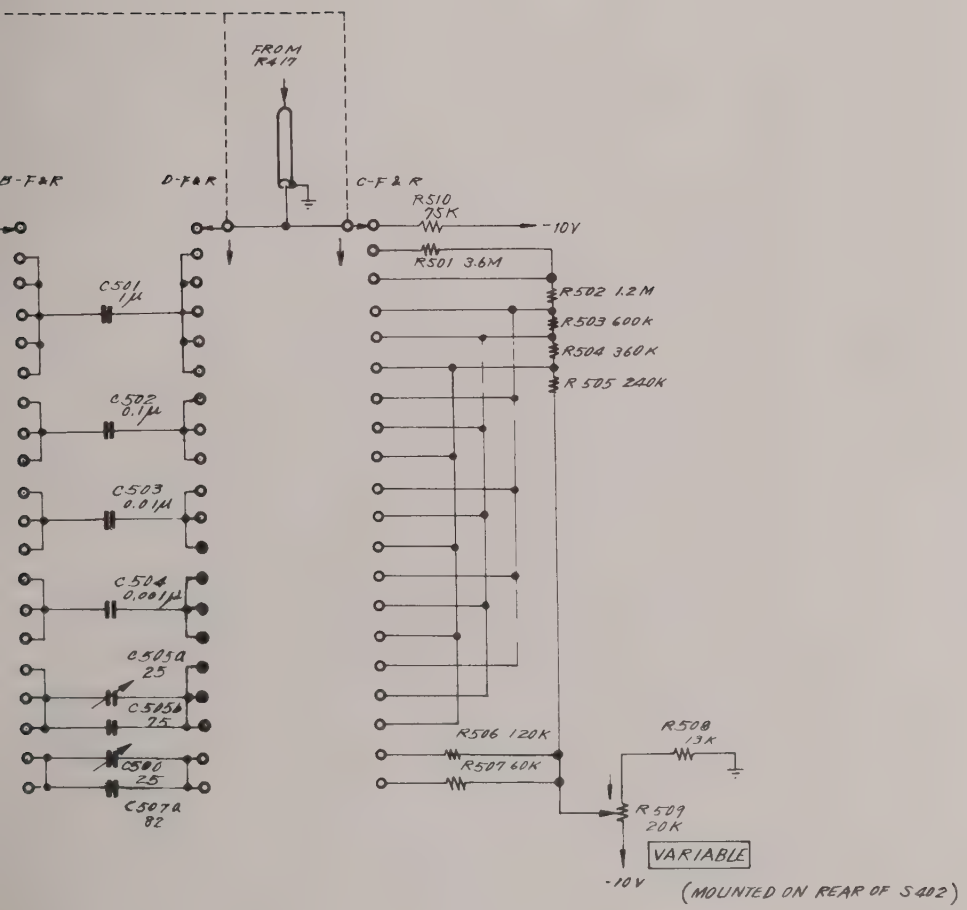
SAWTOOTH GENERATOR

(K-604935-4)

TIMING SWITCH DETAIL ➡


S402
TIME/CM & EXT HORIZ
FROM R431
A-R
FROM R423
C510 10μ
C511 1μ
C512 0.1
C513 0.01
C513b 0.01
C514 0.001
C515 470
C516 100
.5
.2
.1
SEC
50
20
10
5
2
1
.5
.2
.1
m SEC
50
20
10
5
2
1
.5
μSEC

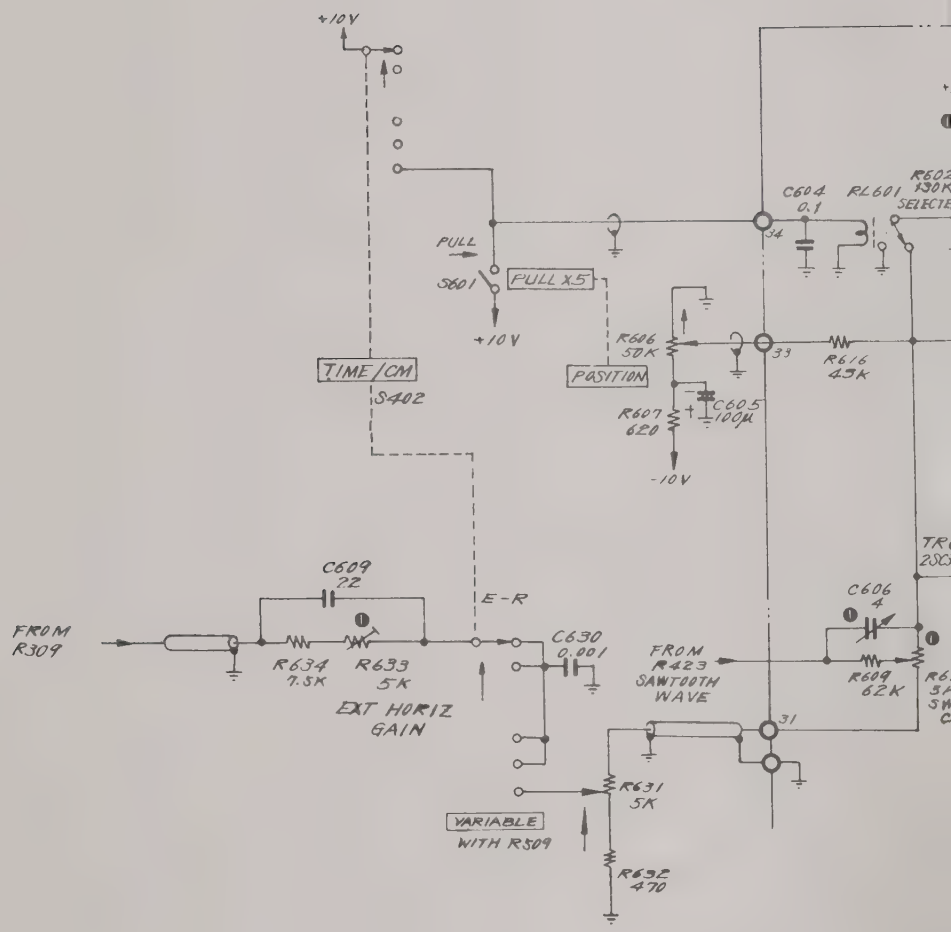


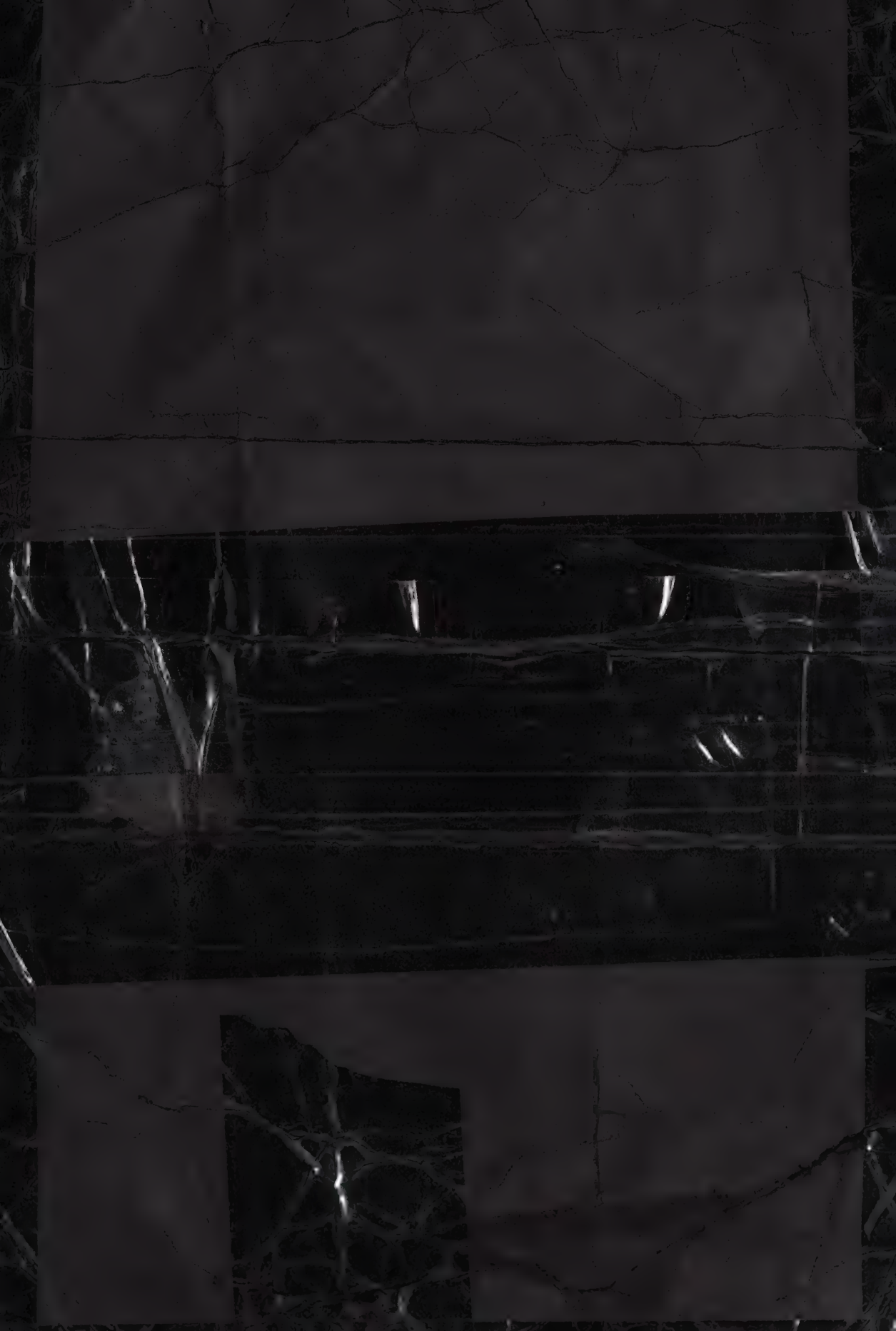


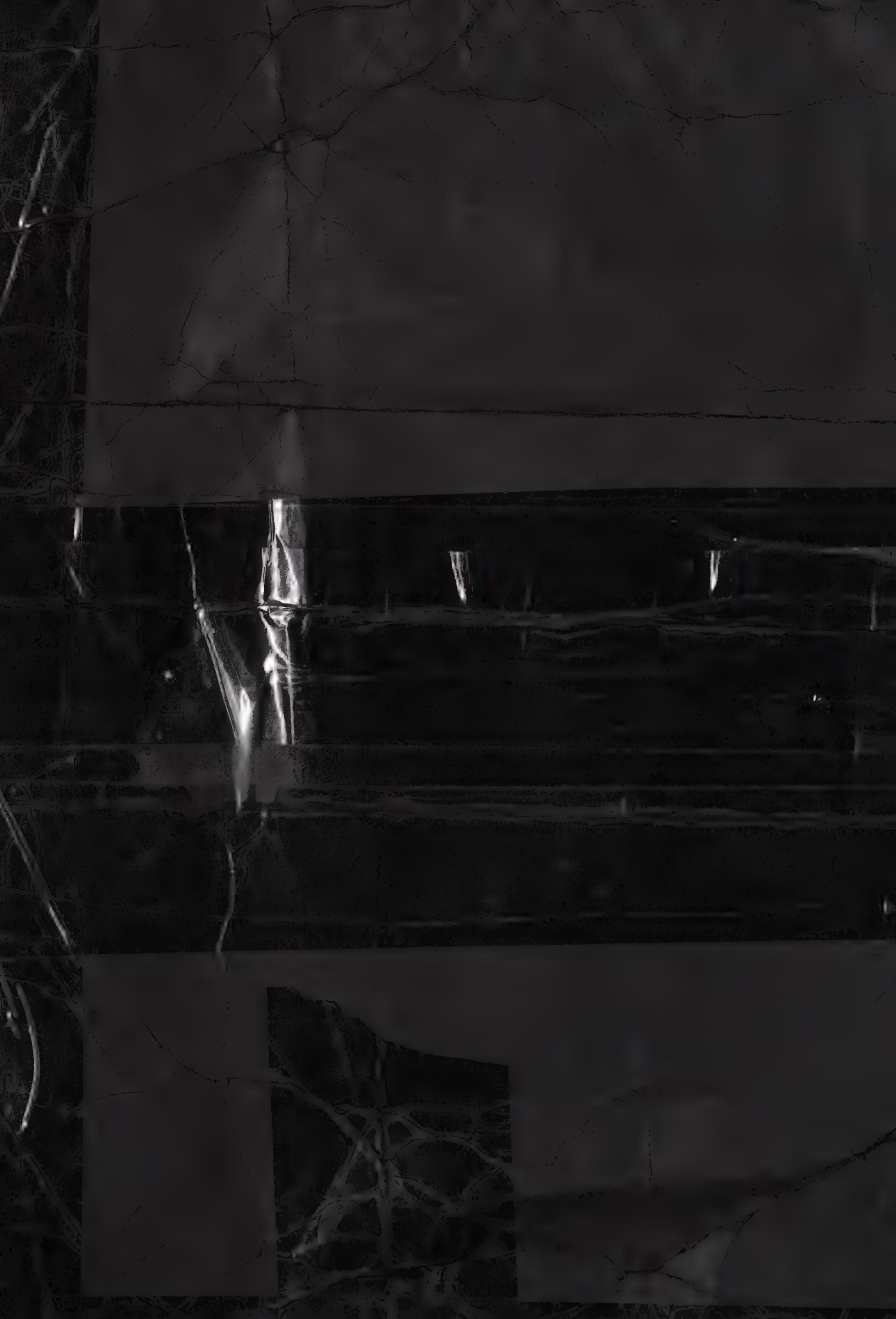
TIMING SWITCH DETAIL

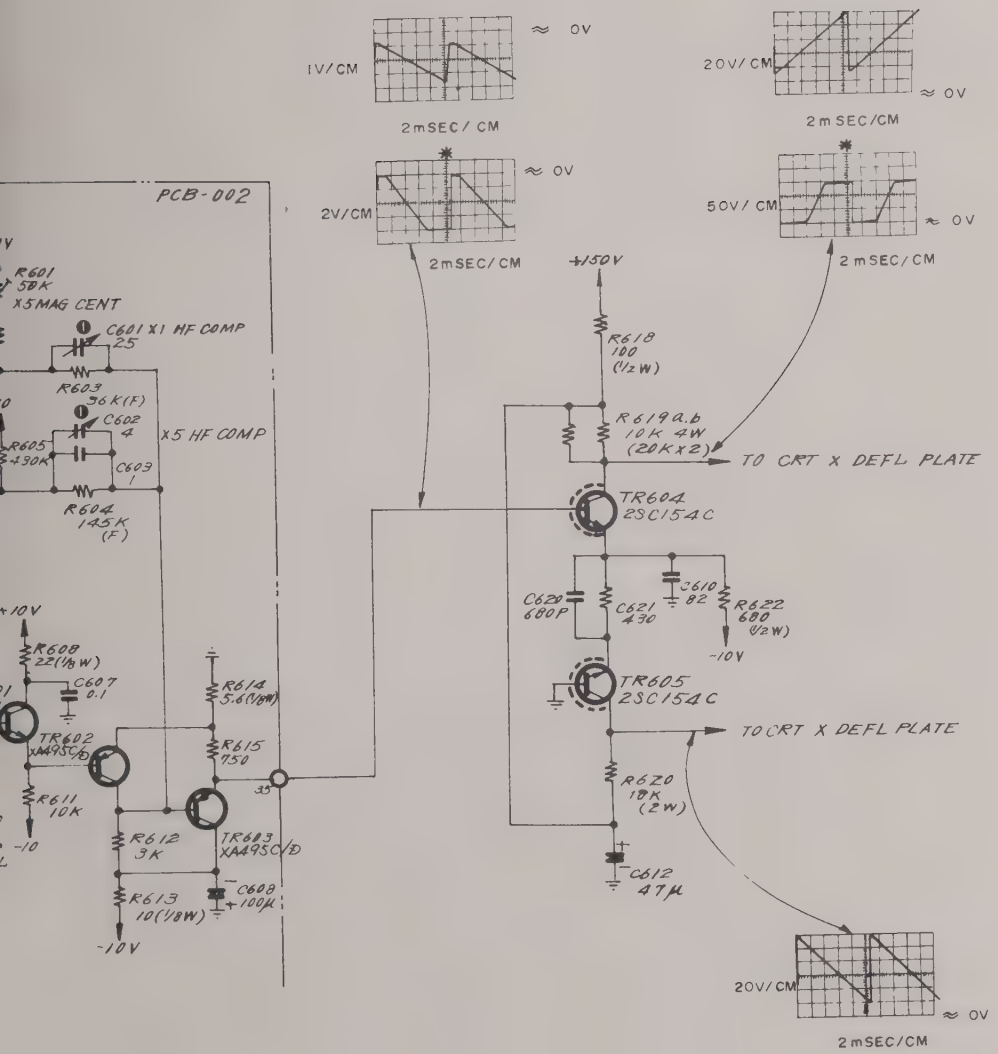
(K-604936-4)

HORIZONTAL AMPLIFIER ➡


+10V
PULL
S601
PULL X5
+10V
TIME/CM
S402
POSITION
R606
50K
R607
620
-10V
C605
100μ
C604
0.1
RL601
34
33
R616
43K
C609
22
E-R
FROM
R309
R634
7.5K
R633
5K
EXT HORIZ
GAIN
C630
0.001
FROM
R423
SAWTOOTH
WAVE
C606
4
R609
62K
31
R631
5K
VARIABLE
WITH R509
R632
470







WAVEFORM READING CONDITIONS

TIME/CM----------/mSEC
PUSH FREE RUN -----PUSH
POSITION---------CENTER

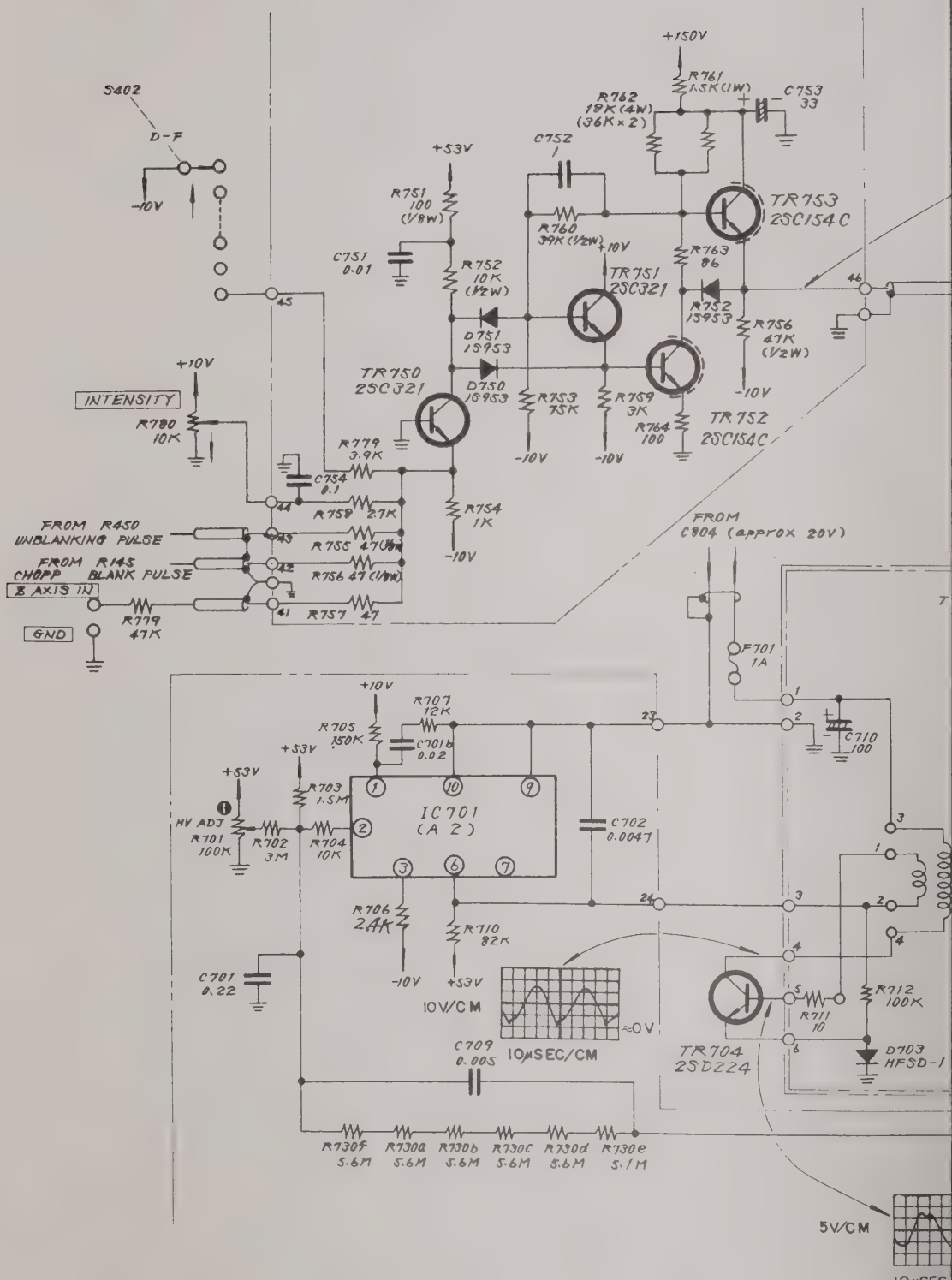
NOTE *

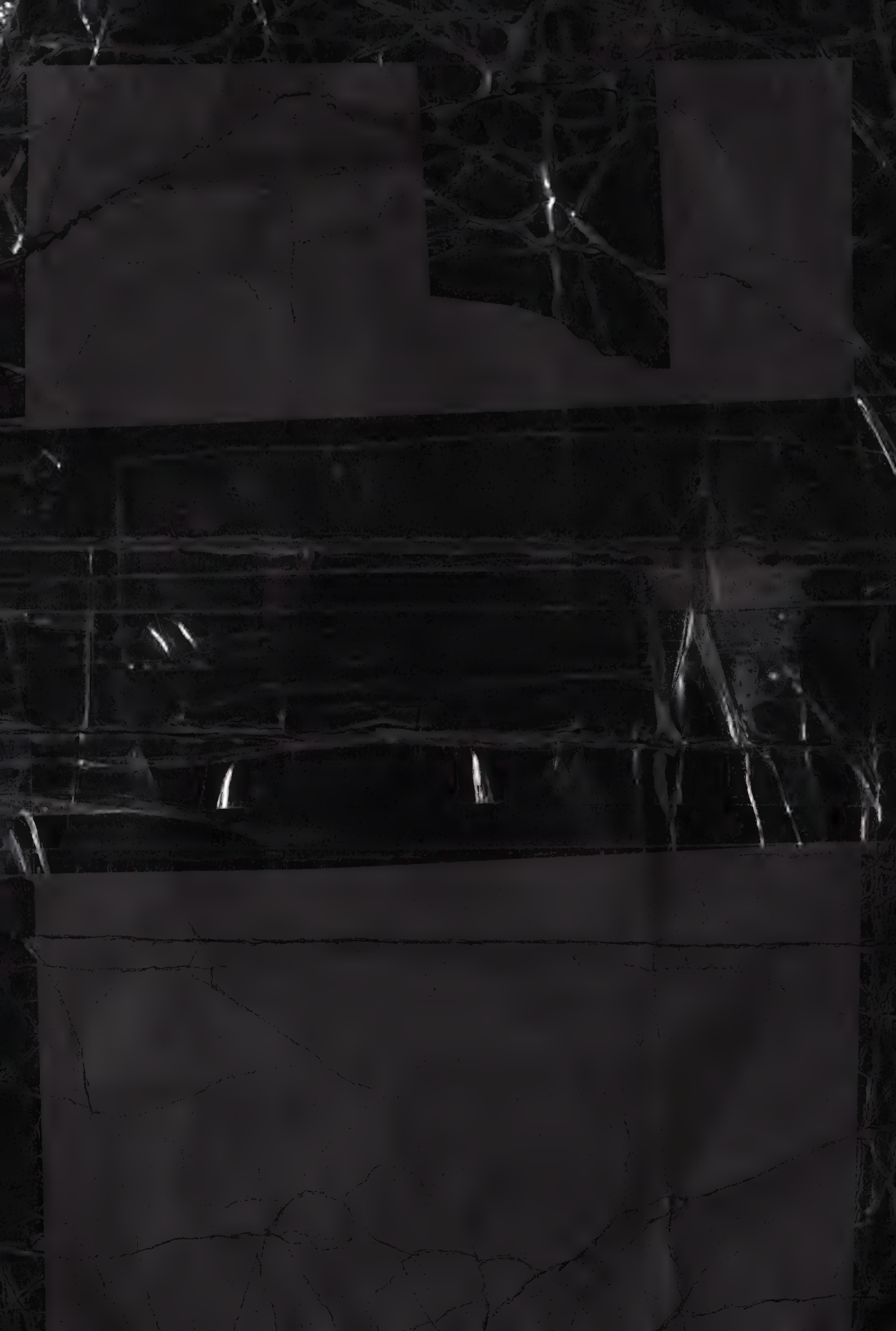
PULL x 5MAG-------PULL

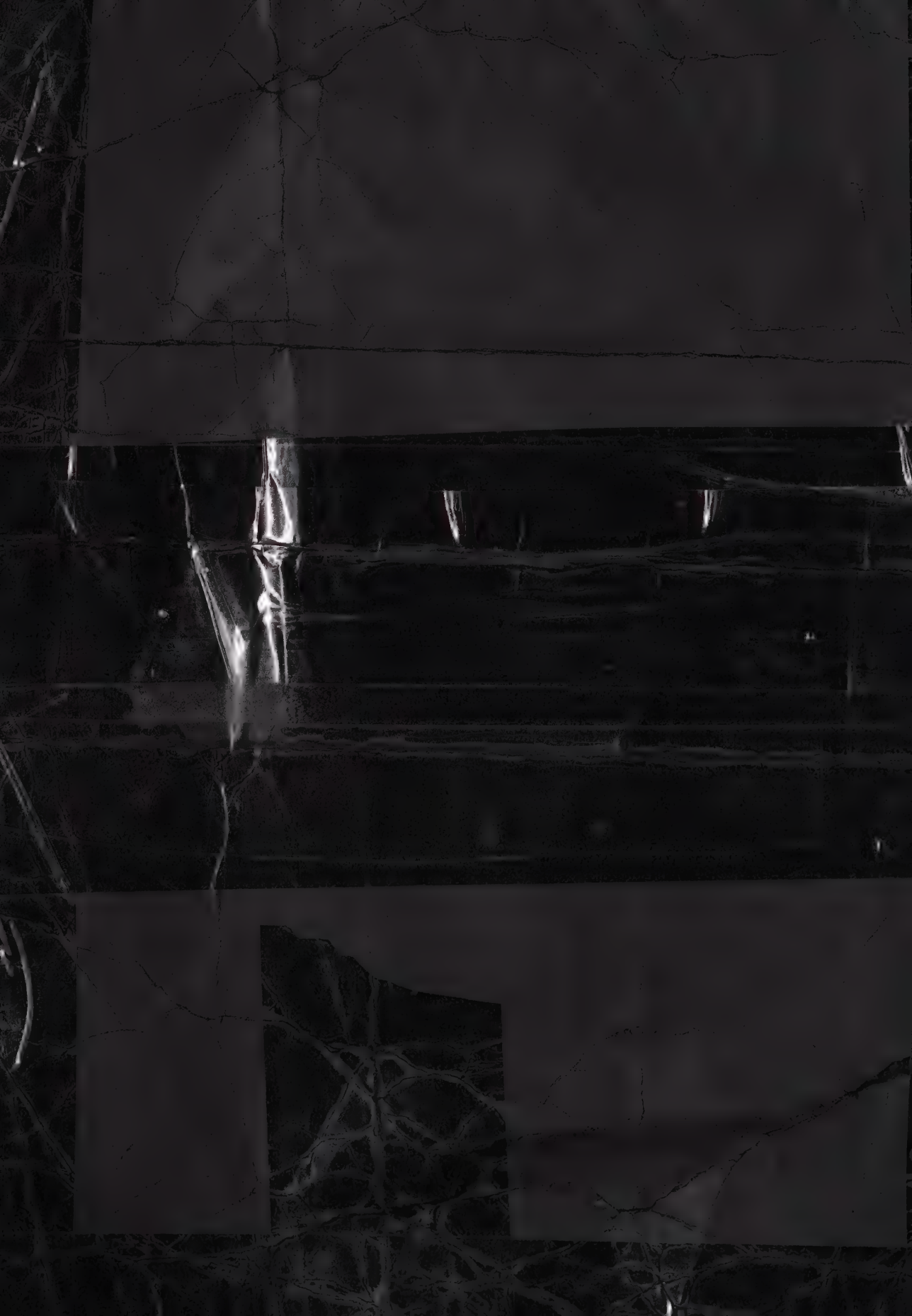
HORIZONTAL AMPLIFIER

(K-604937-2)

CRT CIRCUIT & Z AMP ➡


S402
D-F
-10V
+150V
R761 1.5K(1W)
R762 18K(4W) (36K×2)
C753 33
C752 1
+53V
R751 100 (1/8W)
C751 0.01
R752 10K (1/2W)
R760 39K (1/2W)
+10V
TR753 2SC154C
R763 86
TR751 2SC321
D752 1S953
R756 47K (1/2W)
D751 1S953
TR750 2SC321
D750 1S953
R753 75K
R759 3K
R764 100
TR752 2SC154C
-10V
+10V
INTENSITY
R780 10K
R779 3.9K
C754 0.1
R758 27K
R754 1K
FROM R450 UNBLANKING PULSE
R755 47(1/8W)
FROM R145 CHOPP BLANK PULSE
R756 47(1/8W)
B AXIS IN
R779 47K
R757 47
GND
FROM C804 (approx 20V)
F701 1A
R707 12K
R705 150K
C701b 0.02
C710 100
IC701 (A 2)
HV ADJ
R701 100K
R702 3M
R703 1.5M
R704 10K
C702 0.0047
R706 24K
R710 82K
C701 0.22
10V/CM
≈0V
C709 0.005
10μSEC/CM
TR704 2SD224
R711 10
R712 100K
D703 HFSD-1
R730f 5.6M
R730a 5.6M
R730b 5.6M
R730c 5.6M
R730d 5.6M
R730e 5.1M
5V/CM
10μSEC/





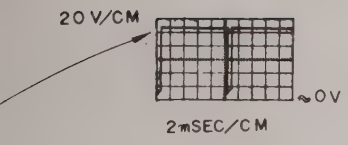
WAVEFORM READING CONDITIONS

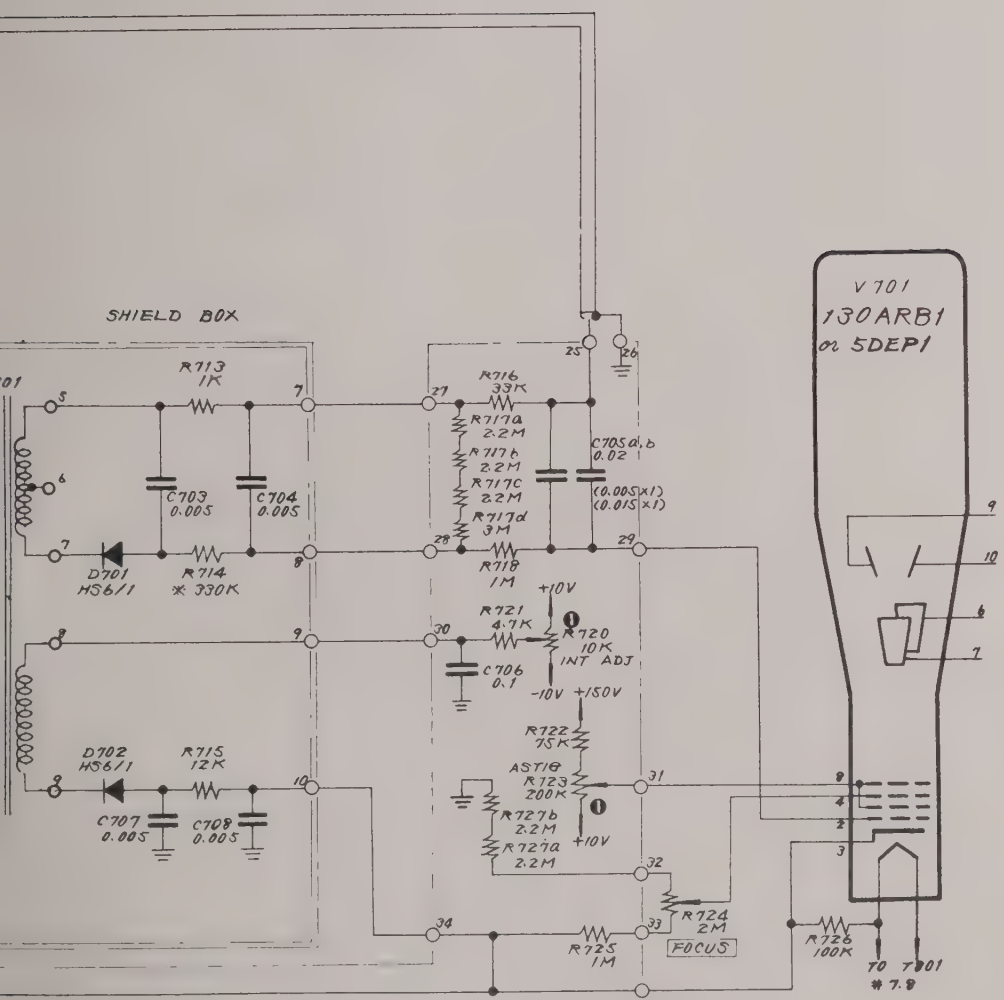
TIME CM ------ 1mSEC

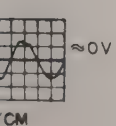
PUSH FREERUN---PUSH

NOTE :

AMPLITUDE VARIES WITH INTENSITY SETTING



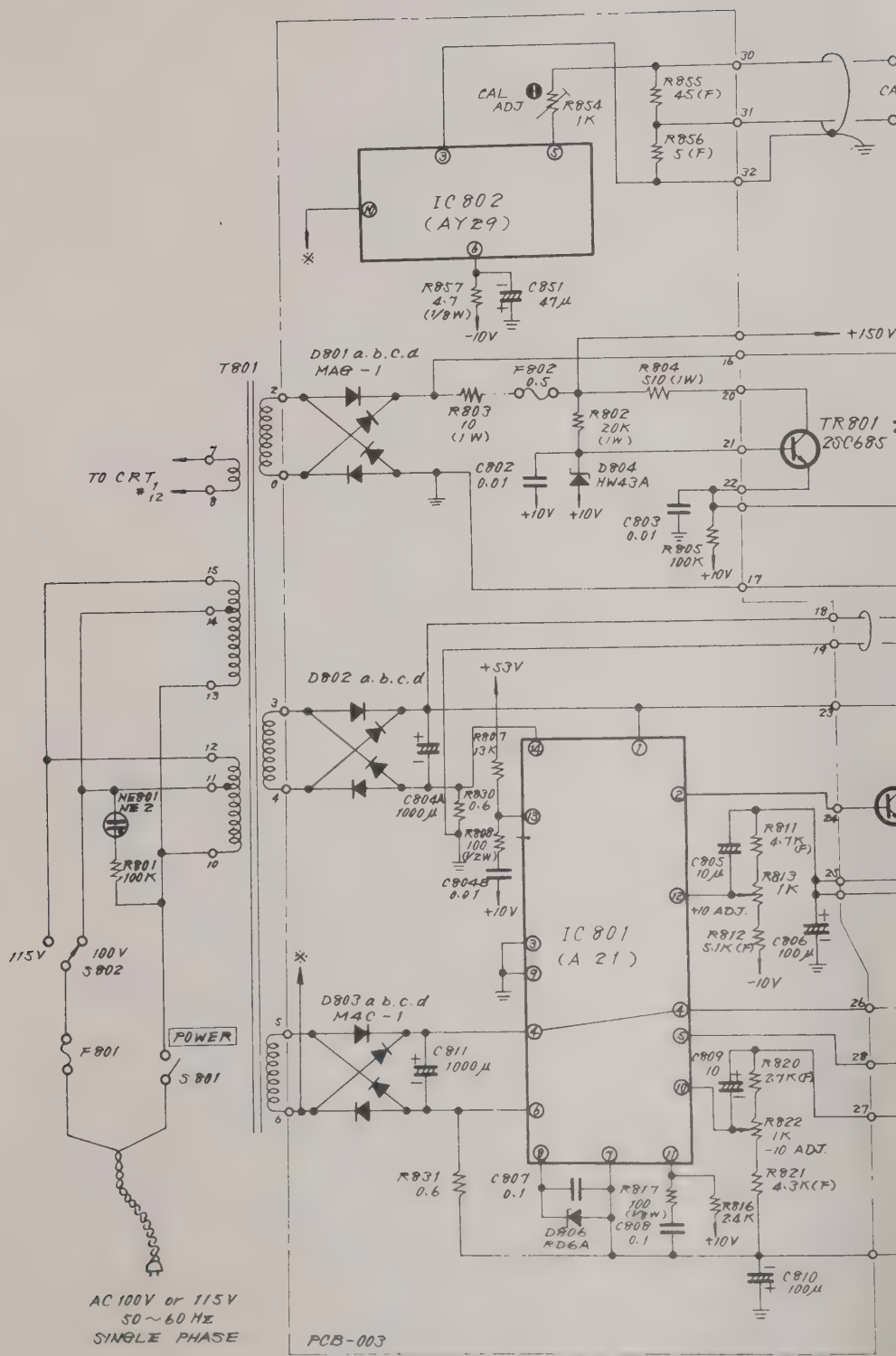


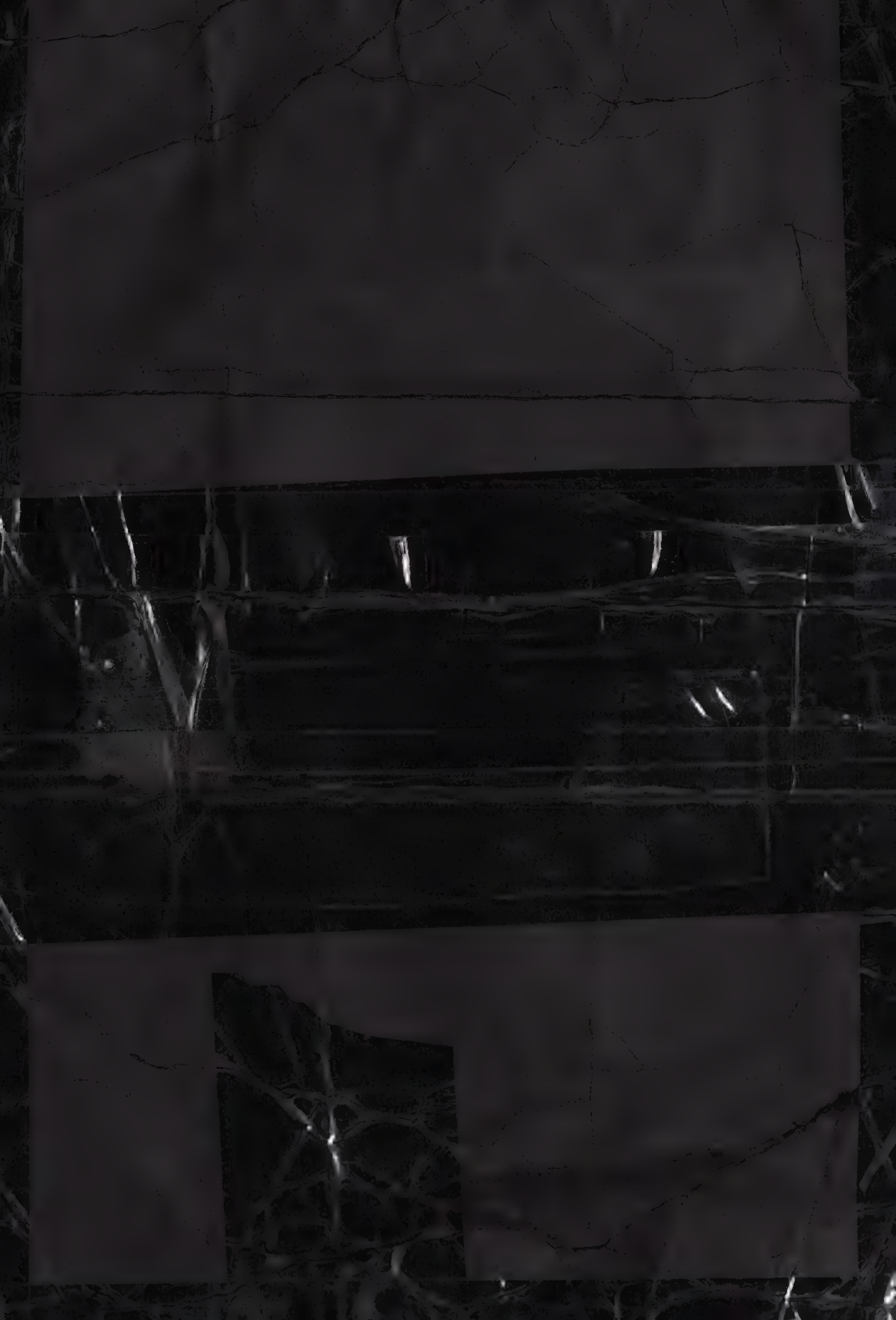


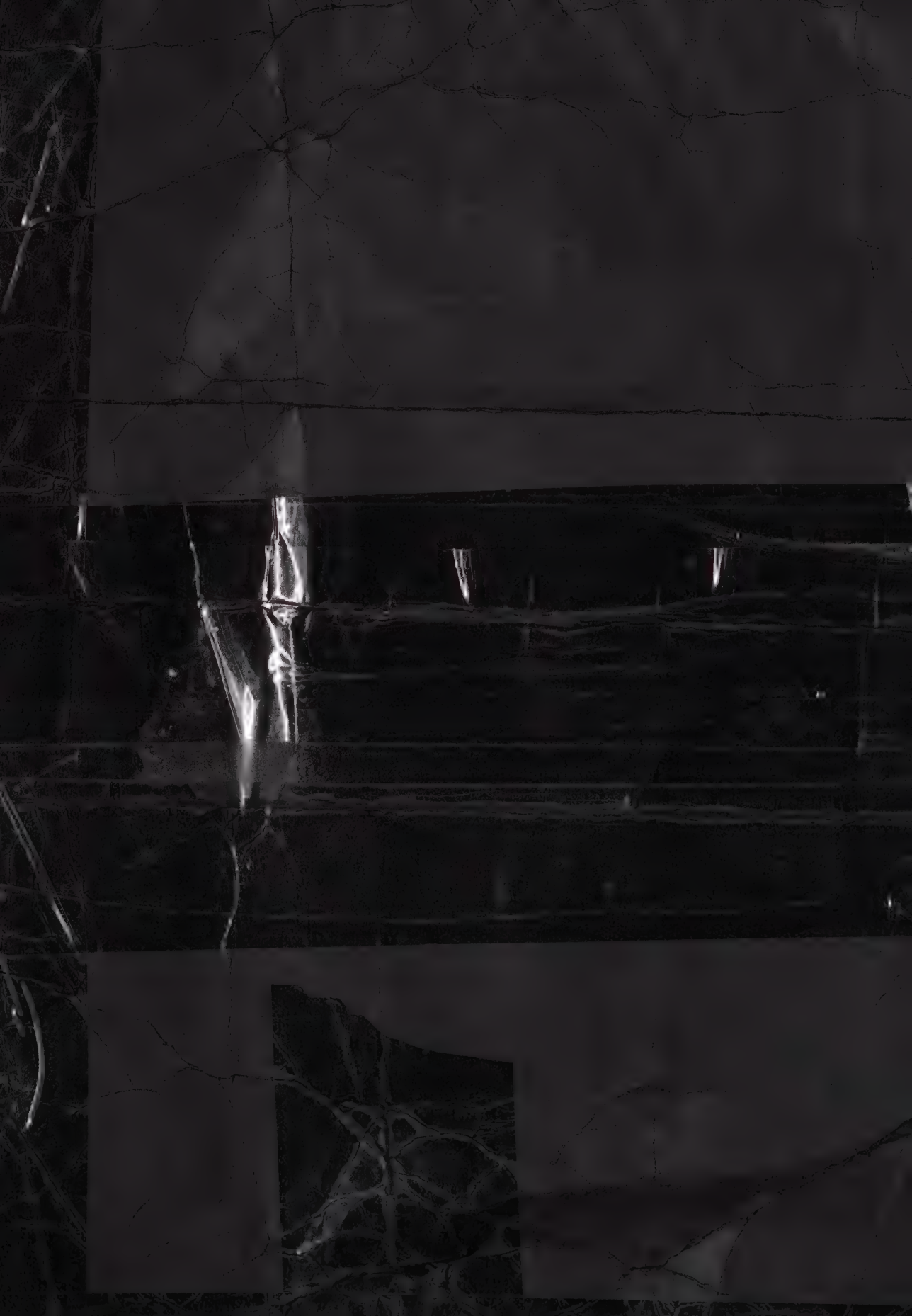
CRT CIRCUIT & Z AMP

(K-605286-3)

POWER REGURATOR ➡


CAL ADJ
R854 1K
R855 4.5(F)
R856 5(F)
IC802 (AY29)
R857 4.7 (1/8W)
C851 47μ
-10V
+150V
T801
D801 a.b.c.d MA8-1
F802 0.5
R804 510 (1W)
R803 10 (1W)
R802 20K (1W)
TR801 2SC685
TO CRT, * 12
C802 0.01
D804 HW43A
+10V
C803 0.01
R805 100K
D802 a.b.c.d
+53V
R807 13K
C804A 1000μ
R830 0.6
R808 100 (1/2W)
C804B 0.01
NE801 NE-2
R801 100K
115V
100V S802
F801
POWER
S801
D803 a.b.c.d MA8-1
C811 1000μ
IC801 (A21)
R811 4.7K(F)
C805 10μ
R813 1K
+10 ADJ.
R812 5.1K(F)
C806 100μ
C809 10
R820 2.7K(F)
R822 1K -10 ADJ.
R821 4.3K(F)
R831 0.6
C807 0.1
R817 100 (1/8W)
R816 2.4K
D805 RD6A
C808 0.1
C810 100μ
AC 100V or 115V 50~60Hz SINGLE PHASE
PCB-003





B801
0.4V

OUT

.04V
B802

C801
100μ

+53V

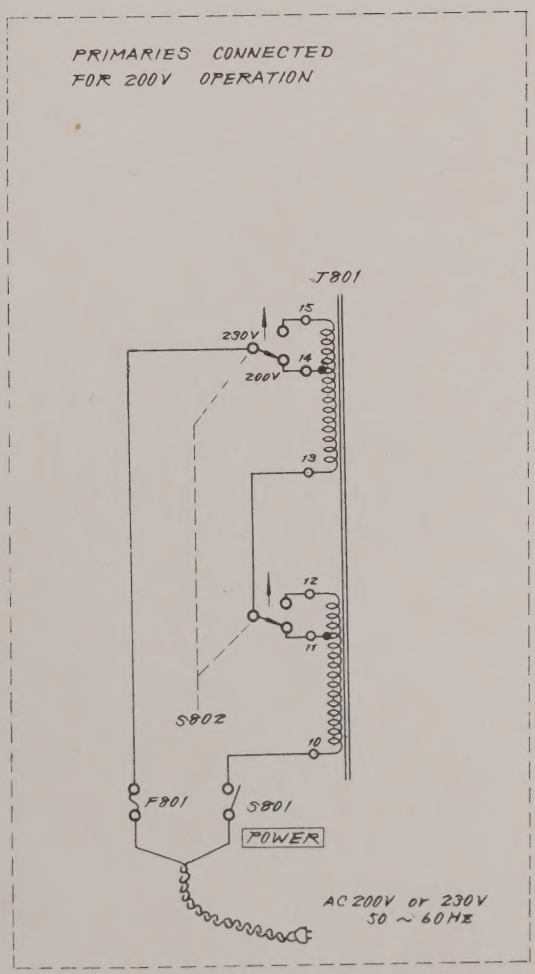
TO F701

TR804
2SD222

+10V

TR808
2SD222

-10V



POWER REGURATOR

(K-605287)

IWATSU

54289